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NASA Contractor Report 3298

Flightworthy Active Control Landing Gear System for a Supersonic Aircraft

Irving Ross

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Flightworthy Active Control Landing Gear System for a Supersonic Aircraft

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I. SUMMARY

This report presents the design of an active control landing gear system for a supersonic aircraft, the purpose of which is to minimize the forces to which the aircraft is subjected as a result of landing impact and rollout, takeoff, and taxi operations. It includes the design of an electronic controller and modifications of the existing landing gear.

The electronic controller compares the kinetic energy of the aircraft with the work potential of the gear until the work potential exceeds the kinetic energy. The wing/gear interface force present at this condition becomes the command force to a servo loop which maintains the wing/gear interface force at this level by providing a signal to an electrohydraulic servovalve to port flow of hydraulic fluid into or out of the landing gear shock strut piston.

II. INTRODUCTION

Hydraulic Research Textron (HR) was retained under NASA Contract NAS1- 15455 to design a flightworthy electronic controller and to design modifications to the landing gear of a supersonic aircraft in order to accommodate active control of the landing gear system which minimizes the aircraft loads during takeoff, landing impact, rollout and taxi. The work was divided into several phases.

(1) Analysis to confirm the performance of the aircraft under conditions of active control of the landing gear. Use was made of a digital computer program developed and supplied by NASA which included aerodynamic simulation and landing gear dynamics. Additions were made to this program to include effects such as line losses imposed by the physical design.

(2) Design of the electronic controller and its packaging.

(3) The hydromechanical design required to reconfigure the landing gear to make it amenable to the active control concept, and the design of associated hardware. In addition, design drawings were prepared for the proper installation of supporting hardware including hydraulic lines and accumulators.

(4) Establishment of the preliminary specification for the electrohydraulic servovalve.

This work was an extension of the work done under NASA Contract NAS1-14459 which involved the design of an electronic controller for an active control landing gear for a light aircraft as described in Reference 1.

Use of trade names or names of manufacturers in this report does not constitute an official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration.

III. SYMBOLS

F_{LC}	limit force command, N (lb)
F_{LI}	value of limit force command during impact, N (lb)
F_{min}	minimum value of F_{wg} for which the force loop remains enabled during rollout, N (lb)
F_{wg}	wing/gear interface force, N (lb)
M	aircraft mass, $N \cdot sec^2/m$ ($lb\ sec^2/ft$)
PE	work potential of the strut, $N \cdot m$ (ft lb)
KE	aircraft kinetic energy, $N \cdot m$ (ft lb)
V_s	aircraft sink rate at touchdown, m/sec (ft/sec)
V_t	transition velocity, m/sec (ft/sec)
V_{wg}	velocity of the wing/gear interface, m/sec (ft/sec)
X_m	maximum strut deflection, m (ft)
X_s	strut deflection, m (ft)

IV. CONTROLLER FUNCTIONAL DESCRIPTION

The controller monitors sensor data and performs computations involving velocity, energy and signal conditioning to provide an output signal which serves as an input command to the servovalve. The controller is designed to operate with the following aircraft-mounted sensors and control hardware.

(1) Wing/gear accelerometer which senses the acceleration (force, assuming constant aircraft mass) at the wing/gear interface. This signal provides the feedback for the force loop and is also used to compute energy. Integration of this signal provides the wing/gear velocity.

(2) Strut pressure transducer which senses the hydraulic pressure in the strut. This signal is used to close the pressure loop which maintains the static design pressure in the strut prior to enablement of the servoloop.

(3) Wheel generator which senses the speed of the wheel upon landing. This signal is used to sense touchdown.

(4) Strut position synchro which senses the strut extension. This signal provides the feedback for the position loop and is also used in the computation of the strut work potential.

(5) Scissors switch which senses weight on gear and is an indication of whether the aircraft is airborne or on the ground. This signal is used to determine the mode of operation of the controller.

(6) Sink rate sensor which senses the sink rate of the aircraft. This signal is algebraically summed with the wing/gear velocity signal to provide the total velocity signal. The controller contains provisions for using a pre-set sink rate if an aircraft-mounted sink rate sensor is not available.

(7) Servovalve which is driven by a signal representing the amplified loop error, as modified by the control laws, and causes hydraulic

fluid to be ported into or out of the strut to maintain the wing/gear interface force at the level of the limit force command.

The characteristics of these components are given in Table I.

TABLE I

CHARACTERISTICS OF AIRCRAFT-MOUNTED COMPONENTS

(Unless otherwise indicated all voltages are dc)

Sensor	Sensitivity	Range
W/G Accelerometer	2 mV/g @ 5Vdc Excitation	± 4.12 g's
Strut Pressure Transducer	0.00232mV/kPa (0.016mV/psi)	1.72×10^4 kPa (2500 psi)
Wheel Generator	19.6 mV/rpm	0-2400 rpm (156 knots)
Strut Position Sensor	19.6 Vrms/m (0.5 Vrms/in) (400 Hz)	0-0.508m (20 in)
Scissors Switch	Discrete - Closed on ground	
Sink rate Sensor	0.1312V/m/sec (0.04V/ft/sec)	
Servovalve	$0.00111 \pm 1.1 \times 10^{-4} m^3$/sec/mA (17.6±1.8 gpm/mA) at 2.068×10^4 kPa (3000 psi)	0.0221 ± 0.0022 m^3/sec (351±35 gpm) at 2.068×10^4 kPa (3000 psi)

The controller has three basic functions which are:

(1) Operating mode determination

(2) Limit-force command determination, and

(3) Control-law implementation

A. Operating-Mode Determination

When the controller is enabled it automatically determines the operating mode-landing or takeoff.

1. Landing Mode. - The controller selects the landing mode if power has been applied and the scissors switch signal indicates that the aircraft is airborne. The landing mode is divided into several phases, each imposing a different functional demand on the controller. These are:

(1) Pre-touchdown

(2) Active control initiation

(3) Transition

(4) Rollout

During the pre-touchdown phase, the system is essentially in a passive configuration. However, the controller provides a bias signal to the servovalve to maintain the strut hydraulic pressure equal to the design charging pressure. This is accomplished by a pressure control loop in which the hydraulic pressure is the feedback signal. During this phase the controller also receives a signal from an external source which is representative of the aircraft sink rate at touchdown. In addition, it monitors the strut deflection. However, the servoloop is not enabled and, therefore, the wing/gear interface force is not controlled.

Active control is initiated when the energy relationships indicate that the work potential of the strut exceeds the kinetic energy of the aircraft. Upon such occurrence, the controller causes the following events to occur.

(1) The servoloop is enabled.

(2) An output is generated which is proportional to the force error as dynamically modified by the control laws. This output is applied to the servovalve.

(3) Energy computations are discontinued.

(4) A constant limit force is maintained.

(5) The strut pressure loop is opened.

(6) The servovalve bias is removed.

(7) The transition velocity is computed and continuously compared to the incremental wing/gear velocity to determine the start of transition.

Transition to the rollout phase occurs when the incremental wing/gear velocity equals the transition velocity. During transition, the controller linearly decreases the limit force command until a pre-set limit value is reached.

The rollout phase commences when the limit force command during transition reaches a pre-set minimum value. During this phase, if the wing/gear force is within a band of ± the limit value, the limit command force is maintained at zero and the force loop is opened. If the wing/gear force exceeds the limit value in either polarity then the force loop is closed and the limit force command is maintained at the limit value, with the polarity of the wing/gear force. The controller remains in this mode until power is removed by means of the cockpit switch which de-energizes the solenoid valves thus isolating the gears from the servovalves.

2. Takeoff Mode. - The controller selects the takeoff mode when (1) a controller-enable signal has been received and (2) the scissors switch signal indicates that the aircraft is on the ground. At takeoff the servoloop is active but the limit force command is maintained at zero.

The sequence of events is shown in the flow diagram of Figure 1.

B. Limit Force Command Determination

Prior to the time when the servoloop is enabled, the limit force command is equal to the wing/gear interface force, but since the servovalve path is open, it has no effect. The value of the wing/gear interface force at the instant the servoloop is enabled becomes the limit force command throughout the impact phase. As indicated above, during the transition phase, the limit force command is decreased linearly at a pre-set rate until it reaches a

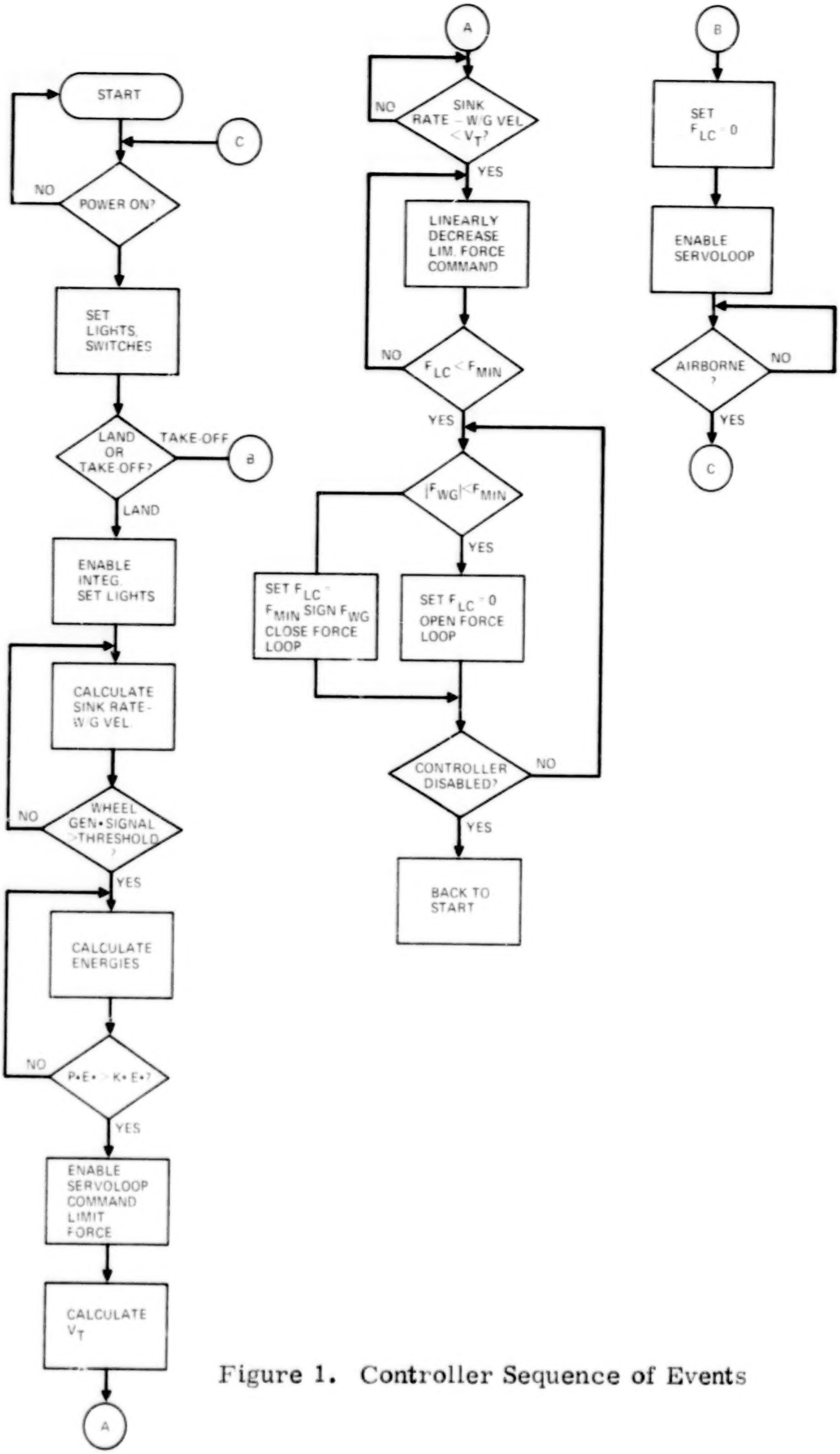


Figure 1. Controller Sequence of Events

pre-set value (F_{min}). After this time, the limit force is zero if the absolute value of the wing/gear interface force is less than F_{min}. If the absolute value of the wing/gear interface force is greater than F_{min}, then the limit force command is equal to F_{min} and its polarity is that of the wing/gear interface force.

In the takeoff mode the limit force command is maintained at zero.

C. Control Law Implementation

The controller implements the control laws as shown in Figure 2 and the transfer functions are shown in Table II.

V. CONTROLLER DESIGN

The controller accepts the following signals:

(1) Wing/gear acceleration (force).

(2) Sink rate.

(3) Strut Position.

(4) Strut pressure.

(5) Wheel speed.

(6) Weight on gear.

It processes these signals to generate:

(1) Wing/gear velocity

(2) Work potential of the strut

(3) Kinetic energy of the aircraft

(4) Limit force command

(5) Transition velocity

(6) Servovalve drive signal

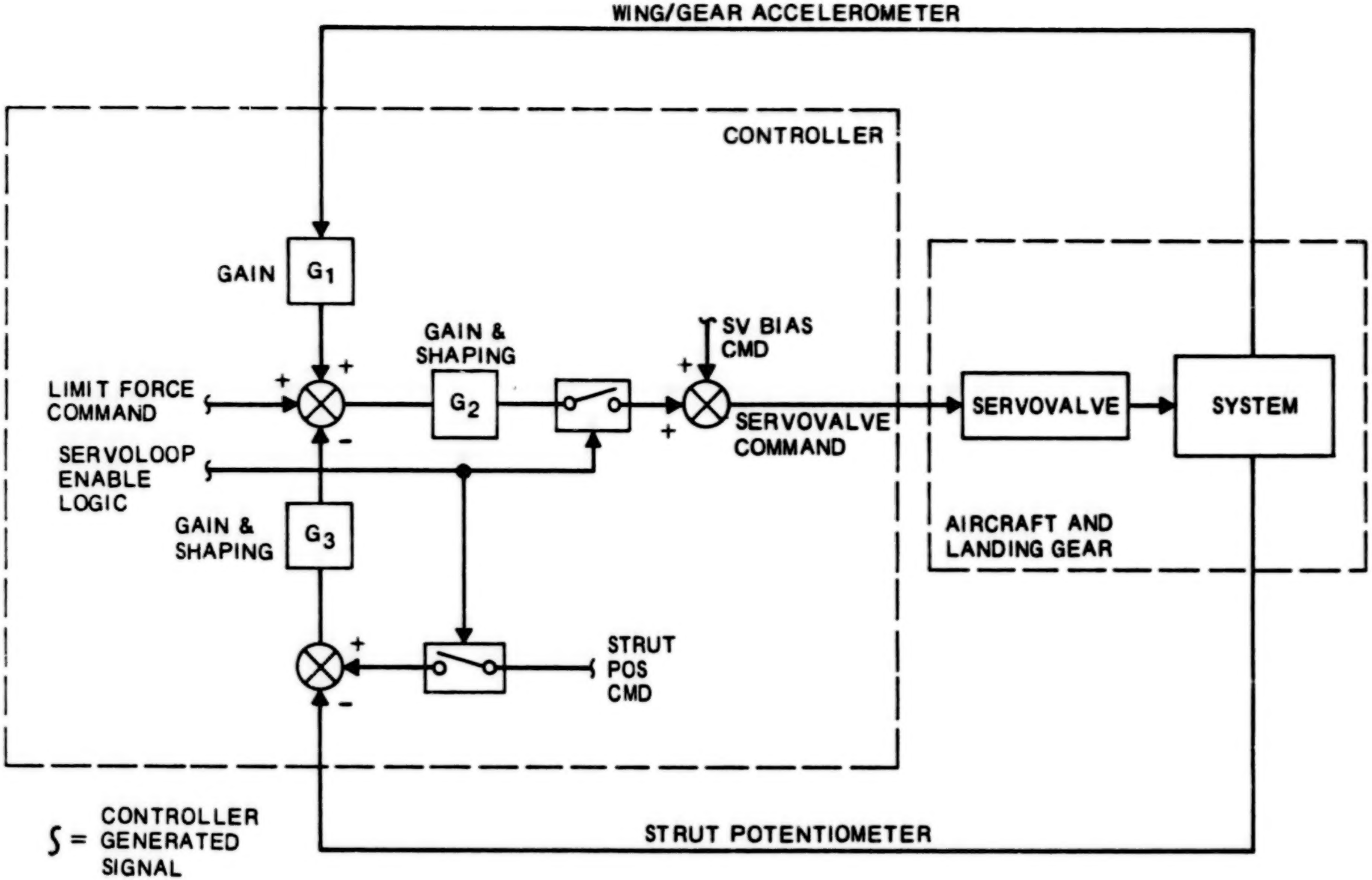


Figure 2. Control Law Functional Schematic

TABLE II. CONTROL LAW TRANSFER FUNCTIONS

SYMBOL (REF. FIGURE 2)	TRANSFER FUNCTION	PARAMETER VALUES
G_1	K_{WG}	K_{WG} = 1.0 V/V
G_2	$\frac{(S^2 + 2\zeta_2\omega_1 S + \omega_1^2)(T_1S + 1)(T_3S + 1)K_A}{(S^2 + 2\zeta_1\omega_1 S + \omega_1^2)(T_2S + 1)(T_4S + 1)}$	T_1 = 0.0281 sec T_2 = 0.0141 sec T_3 = 0.001 sec T_4 = 0.0001 sec ω_1 = 251.3 rad/sec ζ_2 = 0.1 ζ_1 = 5.1 K_A = 1.0 V/V nominal (variable from 50% to 200% of nominal)
G_3	$\frac{K_F}{T_F S + 1}$	K_F = 196.9V/M (5.0V/in.) T_F = 0.1 sec

A. Wing/Gear Velocity

The wing/gear velocity is generated by integrating the wing/gear acceleration signal from the accelerometer mounted at the wing/gear interface. To prevent drift, the integrator is not enabled until touchdown which is indicated by wheel spin-up.

B. Work Potential of the Strut

The work potential of the strut is computed by using an analog multiplier to form the product of the wing/gear force (from the accelerometer) and the available stroke. The available stroke is obtained by subtracting the actual stroke (from the strut position sensor) from the maximum stroke.

C. Kinetic Energy of the Aircraft

Kinetic energy is computed by using an analog multiplier to square the algebraic sum of the wing/gear velocity and sink rate. Since the mass of the aircraft is considered to be constant, the quantity thus obtained is a measure of the kinetic energy.

D. Limit Force Command

As indicated previously, prior to control initiation the limit force command is equal to the wing/gear interface force, but since the servoloop is disabled, it has no effect. The wing/gear force is applied to a sample-and-hold circuit.

After impact, when the two forms of energy become equal, the input to the sample-and-hold circuit is removed, thereby maintaining the limit force command at a constant level, as required. When the total velocity becomes equal to the transition velocity (as described below), the output of the sample-and-hold circuit is allowed to decay; and therefore, the limit force command decreases as required.

When the limit force command reaches a preset value, in the range of 8900 N (2000 lb), then the limit force command is a function of the wing/gear force. If the absolute value of the wing/gear force is less than the preset value (determined by a comparator) the limit force is set to zero. If it is greater than the present value, then the limit force is set to the preset value and given the polarity (sign) of the wing/gear force.

E. Transition Velocity

The transition velocity is obtained by mathematically squaring, by means of an analog multiplier, the value of the limit force command during impact. Since the mass of the aircraft and the transition decay rate are constant, the value thus obtained is a measure of the transition velocity.

F. Servovalve Signals

The loop error signal, which is the algebraic sum of the limit force command, wing/gear force, and position error, is amplified and passed through the shaping networks (derived by means of operational amplifiers and passive components) and applied to the servovalve driver stage which in turn drives the servovalve. The servovalve driver stage produces a current proportional to the input voltage. Prior to servoloop enablement the servovalve driver stage also receives the strut pressure signal to close the pressure loop.

G. Gains and Scaling

1. Wing/Gear Force (F_{wg}). - The sensitivity of the accelerometer is 0.002 V/g. This signal is amplified by a factor of 1500 to product a sensitivity of 3 V/g or 1.102×10^{-5} V/N (4.902×10^{-5} V/lb).

2. Limit Force Command (F_{LC}) - To make the limit force command scaling consistent with the wing/gear force, its scaling is also 1.102×10^{-5} V/N (4.902×10^{-5} V/lb). Therefore, one (1) newton of F_{LC} produces one (1) newton of F_{wg}.

3. Wing/Gear Velocity (V_{wg}). - The scale factor of V_{wg} was chosen to be 3.937 V/m/sec (0.1 V/in/sec). As indicated in (1) above, the scale factor of the wing/gear acceleration is 3 V/g or 0.3060 V/m/sec^2(0.007772 V/in/sec^2). Therefore, the gain of the integrator must be 3.937/0.3060 = 12.86 V/sec/V.

4. Sink Rate (V_s). - To make the sink rate scale factor consistent with that of V_{wg}, its scale factor is also 3.937 V/m/sec (0.1 V/in/sec). If an aircraft mounted sink rate sensor is used its scale factor must be modified by the controller to make it consistent with that of the internally generated V_s. As indicated in Table I, the scale factor of the sensor is 0.1312 V/m/sec (0.04 V/ft/sec). Its signal must therefore be amplified by a factor of 3.937/0.1312 = 30.

5. Force Loop Gain. - To meet the dynamic requirements of the system the "dry-loop" gain of the force loop was chosen to be 0.001937 mA of servovalve current per newton of F_{wg} (0.008615 mA/lb). Therefore, the forward loop gain must be $0.001937/1.102 \times 10^{-5}$ = 175.7 mA of servovalve current per volt of force error.

6. Strut Position (X_s). - As indicated in Table I, the sensitivity of the strut position sensor is 19.69 Vrms/m (0.5 Vrms/in). Since this is a modulated carrier signal it must be demodulated. The gain of the demodulator is 0.5 V dc/Vrms and the resulting scale factor of X_s is then 9.85 V/m (0.25 V/in).

7. Strut Position Command (X_c). - To make the strut position command consistent with the strut position its scale factor is also 9.85 V/m (0.25 V/in). Therefore one (1) meter of position command produces one (1) meter of strut position.

8. Strut Position Loop Gain. - The position loop is required to be effective only under near static conditions and its gain is therefore made quite low. Analysis has indicated that the "dry-loop" gain should be 1.697 mA of servovalve current per meter of strut position error (0.0431 mA/in). As indicated above in paragraph 5, the forward loop gain is 175.7 mA/v and as indicated in paragraphs 6 and 7 the scale factor of the strut position error is 9.85 V/m. Therefore the strut position error must be multiplied by 1.697/ 175.7 x 9.85 = 9.81×10^{-4}.

9. Comparison of Kinetic Energy (KE) and Strut Work Potential (PE). - Work potential is given by $F_{wg} (X_m - X_s)$ where X_m is the maximum compression of the stru' The multiplication is achieved by an analog multiplier with a gain of 0.1. As indicated in paragraph 1, the scale factor of F_{wg} is 1.102×10^{-5} V/N (4.902×10^{-5} V/lb); and as indicated in paragraph 6, the scale factor of $(X_m - X_s)$ is 9.85 V/m (0.25 V/in). Therefore, the scale factor of PE is $(1.102 \times 10^{-5})(9.85)(0.1) = 1.085 \times 10^{-5}$ V/N m (1.226×10^{-6} V/in-lb).

Kinetic energy is given by:

$$\frac{M}{2} (V_s - V_{wg})^2$$

The mass of the aircraft is 2.776×10^4 N sec^2/m (158.5 lb sec^2/in).

Therefore 0.0254 m/sec (1 in/sec) of $V_s - V_{wg}$ produces 8.954 N-m (79.25 in-lb) of KE. $(V_s - V_{wg})^2$ is produced by an analog multiplier with a gain of 0.1 and as indicated in paragraphs 3 and 4 the scale factor of V_s minus V_{wg} = 3.937 V/m/sec. Therefore, for $V_s - V_{wg}$ = 0.0254 m/sec (1 in/sec) the voltage is $\left[(3.937)(0.0254)\right]^2 (0.1) = 0.001$ V. The scale factor for

KE is then 0.001/8.954 = 1.117×10^{-4} V/N-m (1.262×10^{-5} V/in-lb. To compare this with PE it must be multiplied by:

$$\frac{1.085 \times 10^{-5}}{1.117 \times 10^{-4}} = 0.09715$$

10. Comparison of Total Velocity ($V_s - V_{wg}$) and Transition Velocity (V_t).- Transition velocity is given by $(F_{LI})^2/2MR$ where F_{LI} is F_{LC} during impact, and from paragraph 2 its scale factor is 1.102×10^{-5} V/N (4.902×10^{-5} V/lb), R is 4.448×10^{-5} N/sec (100 000 lb/sec) and M = 2.776×10^{4} N sec^2/m (158.5 lb sec^2/in. Then, 4.448 N (1 lb) of F_{LI} produces.

$$\frac{(4.448)^2}{2(2.776 \times 10^4)\ (4.448 \times 10^5)} = 8.012 \times 10^{-10} \text{ m/sec } (3.155 \times 10^{-8} \text{ in/sec})$$

$(F_{LI})^2$ is produced by an analog multiplier with a gain of 0.1. Then 4.448 N (1 lb) of F_{LI} produces:

$$(1.102 \times 10^{-5})\ (4.448)^2\ (0.1) = 2.403 \times 10^{-10} \text{ V}$$

The scale factor of V_t is then:

$$\frac{2.403 \times 10^{-10}}{8.012 \times 10^{-10}} = 0.2999 \text{ V/m/sec } (0.00716 \text{ V/in/sec})$$

From paragraphs 3 and 4 the scale factor for $V_s - V_{wg}$ is 3.937 V/m/sec (0.1 V/in/sec). To compare it to V_t, it must be multiplied by 0.2999/3.937 = 0.07616.

VI. ANALYSIS

Land and roll cases were run using the ACOLAG program supplied by NASA. The variables used for the landing gear model are shown in Figure 3 and the model is described in detail in Reference 1. This model was modified to include the pressure drop effect of the relatively small lines which connect the gear to the pressure source.

Figure 4 compares the results for the active gear, with and without line effects, with those for the passive gear, for a sink rate of 0.914 m/sec (3.00 ft/sec). As can be seen from the figure, the degradation due to the line effect is very small.

VII. LANDING GEAR MODIFICATION

In order to make the gear amendable to the active control concept the following changes were made to the existing gear (refer to Figures 5 and 6).

The landing gear was internally redesigned so that hydraulic fluid could be removed and replaced on demand by the externally located servovalve. This was accomplished by designing a new orifice support tube which added six hydraulic tubes to pick up shock strut hydraulic fluid below the landing gear orifice and transmit it through the top of the landing gear shock strut to an external hydraulic circuit. The hydraulic circuit consists of a servovalve, four (4) accumulators, a relief valve and a solenoid-operated shut-off valve. The accumulators supply fluid to the servovalve at times of high flow demand.

The relief valve was added to protect the internal parts of the landing gear from being over-pressurized. Per the aircraft manufacturer, the internal pressure of the landing gear was designed for $1.517 \times 10^4/2$ kPa (2200 psi) and therefore the relief valve would operate at this pressure.

The solenoid-operated shut-off valves isolate the struts from the servovalves and the aircraft hydraulic system as shown in Figure 6. These valves

will be closed during gear retraction after takeoff and when power is shut off for parking on the ramp.

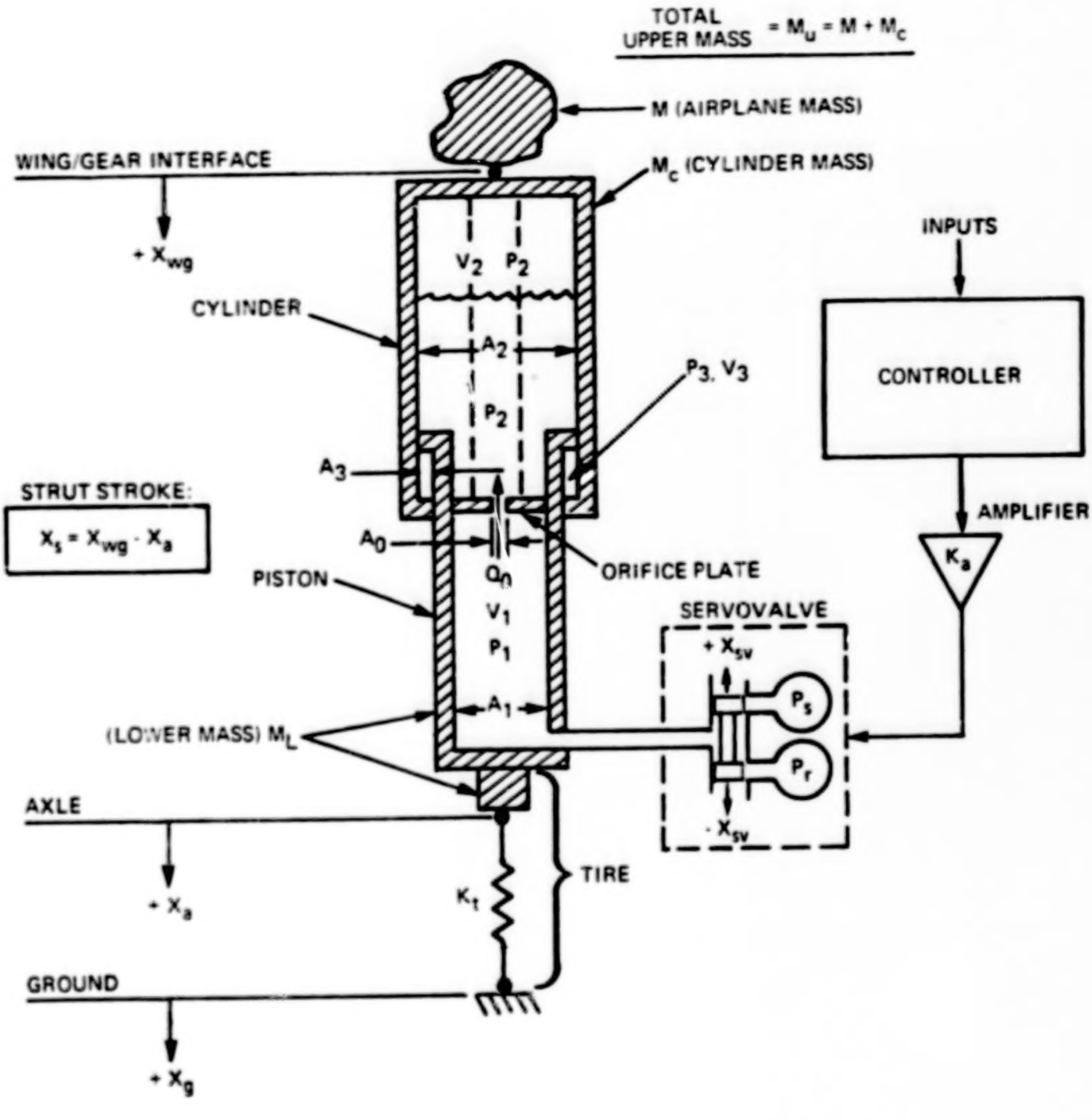


Figure 3. Illustration of variables used in nonlinear simulation of simplified vertical drop case for a single main gear.

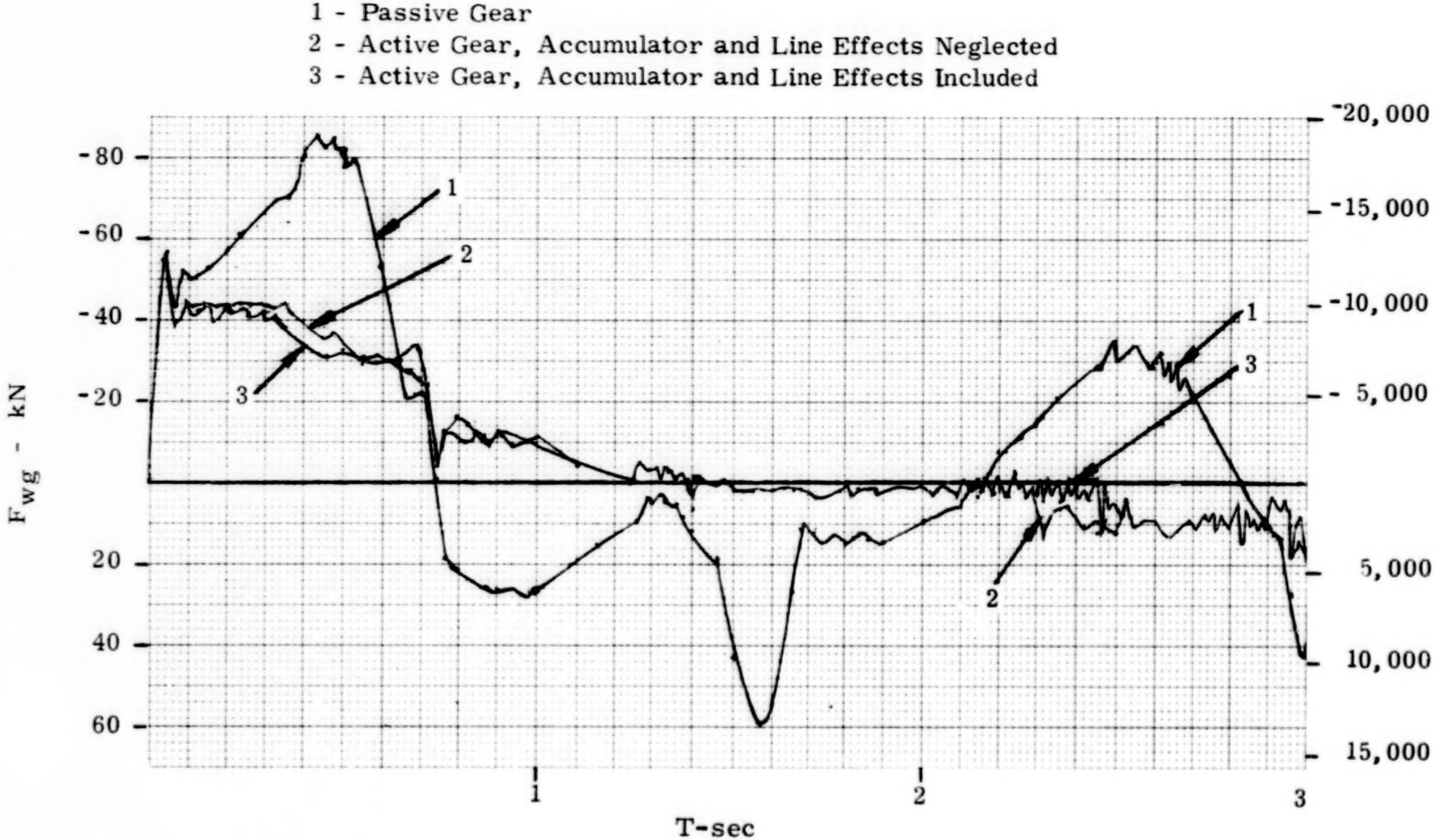


Figure 4. Wing/Gear Interface Force-Time Histories
Sink Rate = 0.914 m/sec (3 ft/sec), Random Runway

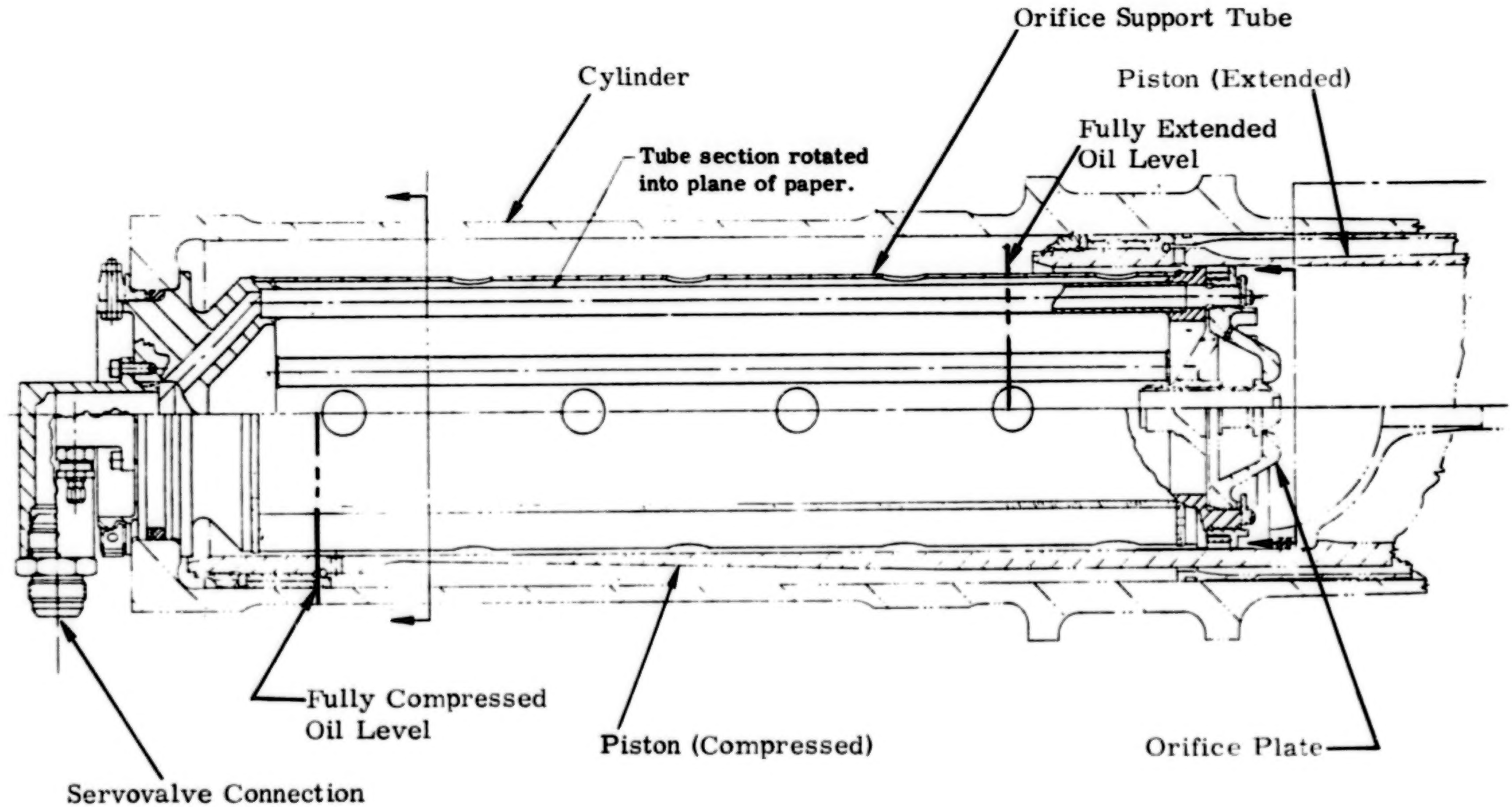


Figure 5. Modified Strut Details

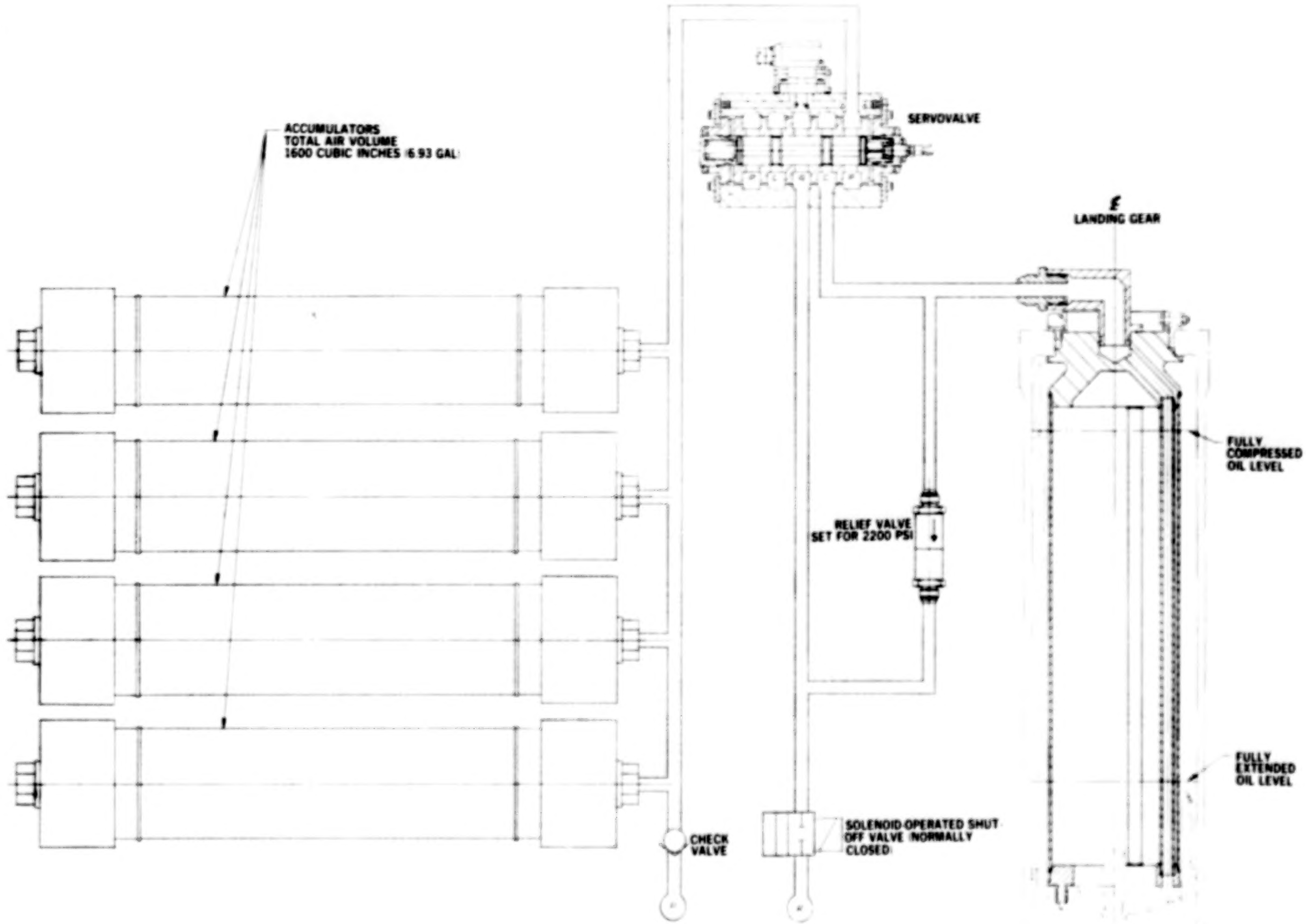


Figure 6. Strut/Servovalve/Accumulator Assembly.
2200 psi = 1.517×10^4 KPa.

The detailed stress analysis of the hydromechanical components is presented as Appendix A. The results of these analyses are summarized in Table III.

VIII. ELECTRONICS

A brief summary of the electronic functions is presented in chart form in Table IV. The complete electronic design is contained in the following drawings:

88000050	Controller Assembly
88000050-200, Rev. A	Schematic (2 sheets)
88000582, Rev. A	P.C. Board Assembly (Channel 1 & 2)
88000583	P.C. Board Assembly (Inter Channel Circuit)
88000583-400	P.C. Board Fabrication
88000584	Chassis
88000585	Gasket
88000586	Cover
88000587	Cover Assembly

These drawings are available at Hydraulic Research, Valencia, CA 91355. A detailed description of the electronic design follows.

IX. DETAILED DESCRIPTION OF THE ELECTRONIC CIRCUITRY

Unless otherwise indicated, the designators refer to the channel 1 and channel 2 boards (A1 and A2). Where the designator refers to the interchannel board or a panel, the number of the board or panel follows the designator in parantheses.

TABLE III
MINIMUM MARGINS OF SAFETY

Part No.	Description	Material	Loading Condition	Min. M.S. Yield	Min. M.S. Ult.	Pages
41004818	Support Assy., Orifice Plate Mlg.	321 CRES	To determine max external & internal pressure assy. can withstand	Max. ext. pressure =	1921 psi	6-10
				Max. int. pressure =	2323 psi	
41004829-101	Tube Assys.	21-6-9 CRES	Pressure(-101) & bending(-104)	1.09	0.98	11-14
-102						
-103			Pressure(-102) (-103) (-107) (-108)	2.26	1.21	11-12
-104						
-105						
-106						
-107			Pressure(-105)	2.15	1.14	15-16
-108			Pressure(-106)	2.12	1.11	16-17
41004819-001	Adapter	15-5 Ph CRES	Pressure	9.32	5.62	19
			Pressure & Moment (Bolt)	-	1.51	20
			(Lug)	-	1.21	20
41004819-007	Servovalve Brackets	6061-T6 Alum. Sheet	Wt. & G loads (Tie-down bolts)	Large	Large	23
			Wt. & G loads (Bracket bolts)	Large	Large	27
			Wt. & G loads (-007)	1.57(Tens.)	-	28
			(-008)	Large(Shear)	-	28
41004819-003	Accumulator	7075-T7351	Wt. & G loads	Large	Large	32
-004	Clamps &	Alum. bar	(thru bolt)			
-006	Brackets		Wt. & G loads (-003)	0.39	-	33-34
41004819-003	Accumulator	7075-T7351	Wt. & G loads	0.62	-	34-35
-004	Clamps &	Alum. bar	(-004)			
-006	Brackets		Wt. & G loads (bolts)	Large	-	35-37
			Wt. & G loads (-006) (A/C Load Reqmts.)	746(Shear)	Per Attachmt.	38
			Wt. & G loads	0.49	-	39-41

TABLE IV

ELECTRONIC FUNCTIONS

Function	Electronic Mechanization
Mode Determination	Flip-flop (U36A) is high or low as a function of scissors switch state
Landing Mode	
Pre-Touchdown	Analog switch U27A is closed to complete the pressure loop to maintain the strut at the design charging pressure.
Touchdown	Flip-flop (U43A) is set when the wheel generator exceeds a threshold level
Sink Rate (V_s)	Pre-set or derived from a sink rate sensor
Wing/Gear Velocity (V_{wg})	Wing/gear acceleration is integrated by U3B
Kinetic Energy	(V_s - V_{wg}) is squared (U11)
Potential Energy	F_{wg} is multiplied by (X_m - X_s) (U19)
Comparison of Kinetic and Potential Energy	Comparator (U13C)
F_{LI} Held Constant During Impact	Sample and hold amplifier (U17) is switched to a hold state by U25A
Servoloop Enabled	Analog switch (U27A) opens the pressure loop and closes the force loop.
Transition Velocity (V_t)	F_{LI} is squared by U18
Determination of Transition	(V_s - V_{wg}) compared to V_t by comparator (U13A)
Decay of F_{LC} During Transition	Ramp is generated by U10D and U8F. Rate is determined by R46 and C16
Comparison of F_{wg} and F_{min}	Comparator (U32C)
F_{LC} Maintained at zero and servoloop Disabled When $/F_{wg}/ \leq F_{min}$	Analog switches (U24A and U34A)
$F_{LC} = F_{min}$ Sign F_{wg} When $/F_{wg}/ > F_{min}$	Sample and hold amplifier (U17)
Take-Off Mode	
$F_{LC} = 0$	
Servoloop Enabled	Analog Switch (U24)
Control Law Implementation	Passive networks associated with U26A, U26B, U26C & U26D

A. Basic Loop Function

The accelerometer signal is amplified by differential amplifiers U1A, U1B and U2A. It is then applied through the panel NORMAL/TEST switch, S6 (A4), to amplifier U3A for inversion, permitting comparators U5A and U5B to determine that the level of the accelerometer signal is within limits of ±3 g's. Otherwise a failure signal is applied to NOR gate U39 and the system reverts to a passive configuration. The accelerometer is also applied through the internal NORMAL/TEST switch, U6A to integrator U3B which produces the wing/gear velocity signal.

Under active control the accelerometer signal is subtracted from the limit force command signal in amplifier U20C to produce the force error signal, which is applied to the compensation circuits of amplifiers U26A, U26B and U26C. The compensated signal is applied through switch U27A to amplifier U28A and then a limiter which is composed of diodes CR12, CR13, CR14 and CR15. The output of the limiter is applied to amplifier U28C, the output of which feeds the constant current amplifier U29 which, in turn, drives the servovalve. If a failure is detected then switch U34B removes excitation from U29 and therefore prevents the servovalve from being driven.

B. Take Off Mode

Several functions begin when power is turned on, while the aircraft is at rest, and are listed below. In the description of these functions, where sink rate (V_s) is involved, the sink rate is an input value rather than one supplied by a sink rate sensor.

(1) The scissors switches are closed indicating that the struts are partially compressed.

(2) The "power-on" transient provides RESET of all circuit flip-flops

by means of C1 (A4), R2 (A4), U1A (A4, and U1B (A4) and also energizes the isolation solenoid valves to expose the fluid in the landing gear shock strut pistons to the servovalves and the aircraft hydraulic system.

(3) The tachometer output is low.

(4) The strut position voltage is greater than 0.2V as determined by comparator U41B, indicating that the strut is partially compressed.

(5) Analog switch U6A is in the NORMAL mode which inputs the F_{wg} signal into U3B which is <u>not</u> integrating, making the V_{wg} signal near zero, since capacitor C1 is short-circuited by switch U6B.

(6) The kinetic energy calculation $(V_s - V_{wg})^2$ is operative at a maximum high level since V_{wg} is near zero. The input sink rate voltage, V_S, is applied to multiplier U11 via analog switch U12A, while V_{wg} is applied from U3B via inverting amplifier U7A.

(7) The potential energy is calculated by U19, performing the function $(X_m - X_s)\ F_{wg}$. This value is smaller than $(V_s - V_{wg})^2$ so that K.E. > P.E. and IMPACT flip-flop is not set to IMPACT.

(8) The sample/hold amplifier U17 is in the SAMPLE mode and F_{wg} is near zero. The level of F_{wg} is processed by the sample/hold amplifier and supplied to the various circuit points for calculation, including the input to U26A via U6A, U34A and U20C to close the force loop.

(9) The output of the sample/hold amplifier is applied to U18 for calculation of F_{LC}^2, (which is F_{wg}^2 at this time), and near zero.

(10) For a preset sink rate the values of F_{LC}^2 at the output of SAMPLE/HOLD amplifier, U17 and V_{wg} from U3B and U7A are small in comparison to the input sink rate voltage and therefore U13A does not set TRANSITION mode flip-flop U14A.

(11) The strut pressure amplifiers, U2B, U2D, and U2C, are operative but the output voltage is not introduced by U27A to the servoloop since gate U25B has high level inputs from IMPACT flip-flop U14B and AIRBORNE gate inverter U36A. That is, U27A is switched to the SERVO mode since the status is not AIRBORNE and IMPACT was not experienced.

(12) Analog switch U6B is not energized, leaving the switch closed around integrating capacitor C1 in amplifier U3B, making V_{wg} near zero.

(13) AIRBORNE flip-flop U5A (A4) is in the RESET state and the TAKE OFF lamp is energized.

(14) The force loop is closed. Analog switches U24A and U34A are closed so that F_{LC}=O and F_{wg} is fed back to the servo loop.

(15) The demodulated strut position signal is applied through U16A, the normal test switch, U12B, U20D, and U24B to U26A to close the position loop.

(16) In the passive test mode, the eight (8) input NOR gate, U39 has low-level inputs indicating the following:

F_{wg} is less than ± 3 g's (the output from U5A and U5B is low)

Synchro has 400 Hz excitation, evidenced by a low output from excitation comparator U13B as controlled by amplifier U16C and rectifier amplifier U16D

Magnitude of servovalve spool feedback is less than 2 volts as determined by feedback comparators U38A and U38B when differential signals from the demodulator are applied to them. The spool feedback is sensed by the LVDT excited by oscillator U32A and buffer amplifier U33.

Current is flowing in the coil of servovalve as detected by amplifier U35B, detector U35D and amplifier U31D. A low level input to NOR gate U39 is evidence of a satisfactory current level. Inputs at pins 2, 5, 11 and 12 of U39 must be low to prevent failure of the test.

The remaining inputs are not used at this time.

C. Aircraft Take Off

Several circuit changes accompany aircraft take-off as follows:

(1) The tachometer voltage increases with the ground speed of the craft and returns to zero as the wheels spin down after lift-off.

(2) The scissors switches change from closed to open as the aircraft takes off.

(3) The landing gear struts become fully extended upon take-off and the output voltage from position amplifiers U1C, U16B, and U16A nears zero.

(4) When the wheels spin down to near zero, the conditions in 1, 2, and 3 above are used to establish an AIRBORNE signal.

(5) When both channels have developed an AIRBORNE signal, U5A, AIRBORNE flip-flop (A4) is set to the AIRBORNE state and the LANDING MODE lamp is illuminated. The aircraft can now land under active control. If the LANDING MODE is not desired the pilot can remove power from the system which closes the solenoid valves and isolates the struts from the servovalves and the aircraft hydraulic system.

D. Flight

The circuits continue to function during flight as long as power is applied. If the TEST switch is closed the passive inputs of U39, pins 2, 5, 11, and 12 will be augmented by the following:

(1) The strut is tested for extension by comparator U41B. If the strut position voltage is less than 0.2 V, the #9 input to U39 will remain low and no failure will be indicated. This test can be conducted only between AIRBORNE and TOUCHDOWN.

(2) A RESET signal is applied to all of the SET-RESET flip-flops following the TEST interval. The AIRBORNE flip-flop U5A (interchannel schematic) immediately returns to the SET state since the inputs remain high during flight.

E. Pre-Touchdown

The servo loop is switched to a pressure control configuration by STRUT PRESSURE analog switch U27A which is activated by gate U25B. The gate is enabled after AIRBORNE flip-flop U5A (A4) is set and prior to IMPACT flip-flop action. In this configuration the servo loop maintains the strut pressure at the pre-touchdown bias (charging) level. The solenoid valves are energized to permit control by the servovalves.

F. Landing

This procedure begins with TOUCHDOWN and continues through ROLLOUT. The controller accomplishes the following:

(1) The signal for TOUCHDOWN is derived from the tachometer signal when it exceeds the input threshold of U44. TOUCHDOWN flip-flop U43A is SET to register the event.

(2) Integrator U3B begins to integrate the F_{wg} signal from accelerometer amplifiers U1A, U1B, and U2A. Gates U10A and U9A and amplifier U8A provide a high-level signal to U6B to remove the short from integrating capacitor C1.

(3) Values of F_{wg} are integrated by U3B and applied to U11 via U7A as V_{wg} for calculation of kinetic energy $(V_s - V_{wg})^2$.

(4) The F_{wg} signal is applied to U19 along with the strut position signal $(X_m - X_s)$ from U16A for calculation of potential energy, $(X_m - X_s) F_{wg}$.

(5) The output of comparator U13C goes high when PE $\geq$ KE and SETS U14B IMPACT flip-flop to the IMPACT state. At this point, sample/hold amplifier U17 is switched to the HOLD state by the IMPACT state entering U25A.

(6) At the IMPACT state, the servo loop is switched from the pressure loop to the force loop by analog switch U27A and the loop acts to maintain F_{wg}

by U24A closing the shorting switch across C1. This is accomplished by U6B via U10A. The force loop compares F_{wg} to the constant value of F_{LC} provided by sample/hold amplifier U17 and a signal is applied to the servovalve to maintain F_{wg} equal to F_{LC}.

(7) Amplifier U18 squares the now constant value of F_{LC} and applies the output to comparator U13A to determine when $(F_{LC})^2 = (V_s - V_{wg})$ which SETS flip-flop U14A TRANSITION flip-flop to the TRANSITION state.

(8) The TRANSITION state is also used to enable U10D and U8F to develop a RAMP gate for U17 where the level of F_{LC} is reduced at the rate of 445 kN/sec (100 klb/sec) or 4.902 V/sec, by the discharge of R46 and C6.

(9) The servo loop controls F_{wg} to the F_{LC} ramp reference until F_{wg} reaches F_{min}. At this point the F_{wg} signal is less than -96 mV and comparator U32C output goes positive. Since U14A is now SET to the TRANSITION state, U10B is enabled and ROLLOUT flip-flop U43B is SET to provide the ROLLOUT interval.

(10) When ROLLOUT begins, the ramp gate to U17 is shut-off by U10D and U8F. The output of camparator U41C remains high so that U10C is at a high level, permitting analog switches U24A and U34A to operate, making the servo loop reference $F_{LC} = 0$ and disconnecting F_{wg} from the servo loop. This action leaves the servo loop connected as a position loop without a force signal feedback.

(11) The sample/hold amplifier U17 remains in the hold state even though the ramp gate is terminated and the calculations of force parameters are no longer needed.

(12) The output F_{wg} continues from $+F_{min}$ through zero and beyond $-F_{min}$ where comparator U41C shifts to the low logic level causing sample/hold amplifier U17 to perform a short sample of F_{wg} at near $-F_{min}$ and hold this value for reference to the servo force loop which has again become active as F_{wg} is greater than F_{min}. The servo loop now maintains F_{wg} equal to F_{LC} at a level of F_{min} during this interval.

(13) A return of F_{wg} to less than F_{min} will cause the servo loop to revert to the position loop configuration and analog switches U24A and U34A make $F_{LC} = 0$.

(14) Any further excursion of F_{wg} beyond $\pm F_{min}$ will cause the sample/hold amplifier to sample, (as driven by U25A), and establish a servo loop reference of $F_{LC} = F_{min}$. The force loop will then be closed to maintain F_{wg} at F_{min}.

(15) The last portions of ROLLOUT will find F_{wg} less than F_{min} and the servo loop controlling position with $F_{LC} = 0$ and $F_{wg} = 0$ as a result of analog switches U24A and U34A as driven by U9D.

(16) After ROLLOUT begins F_{wg} can no longer be a signal to the servo loop unless F_{-wg} exceeds F_{min}. Otherwise, the system has position loop activity only.

To take off again with the force loop closed the controller must be RESET by turning the power OFF and then ON again.

G. Control (Loop Compensation) Laws

The compensation consists of a notch network and two lead-lag networks. The notch network is implemented by means of the passive components associated with U26A. One lead-lag network is implemented by means of the passive components associated with U26B while the other lead-lag network is implemented by means of the passive components associated with U26C.

H. Description of Controller Tests

1. Continuous Tests. - Several tests are made continuously while the controllers are powered. These are as follows:

(1) F_{wg} is less than $\pm$ 3 g's

(2) Synchro has 400 Hz excitation.

(3) Magnitude of servovalve spool signal is less than 2 V, (LVDT test).

(4) Current is present in the EHSV coil.

2. Pilot Initiated Tests. - Tests which can be made upon Push-to-Test command only are:

(1) Strut partially contracted when not airborne

(2) Strut position extended when airborne.

(3) Dynamic Test.

All signals are applied to U39 for composition of the failure circuits into a single command source, as illustrated in Figure 7.

3. Detailed Description of test inputs for dynamic test. -

The test inputs and relative timing are shown in Figure 8 . This test is performed by introducing a voltage representing 0.1 g (-0.3 volts), a voltage representing V_s (10 V) and a voltage representing $X_m - X_s$ (0.5 V) into the system and establishing a test based upon this input. The following functions are performed.

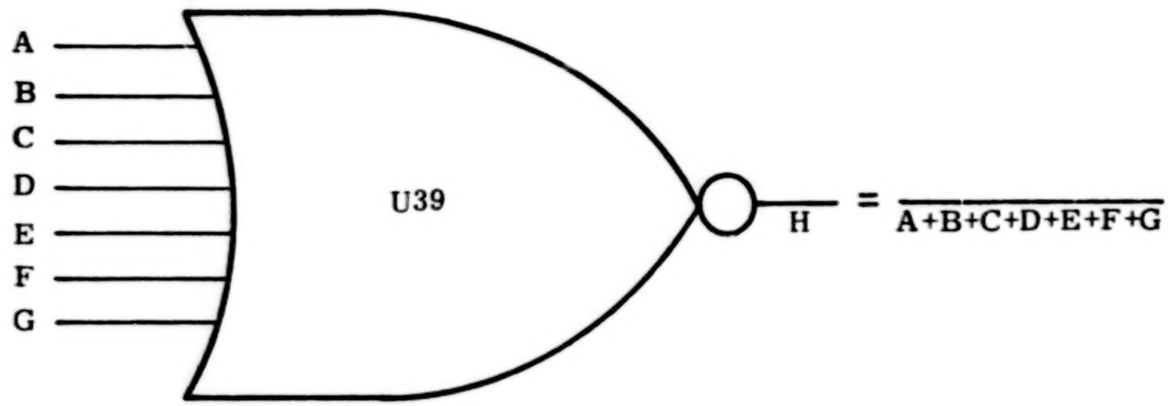
(1) U6A analog switch is set to TEST position and -0.3 V is introduced to integrator U3B as a F_{wg} signal.

(2) U6B is enabled to open the short around C1 and F_{wg} is integrated by U3B.

(3) U11 performs the calculation for kinetic energy, $(V_s - V_{wg})^2$.

(4) Analog switch U12A is switched to a reference value for V_s of + 10.0 volts for the calculation of kinetic energy.

(5) U12B analog switch is switched from the strut position signal to a reference of 0.5 V representing $(X_m - X_s)$.



A = Dynamic Test (Pin 4)
B = F_{wg} Level (Pin 5)
C = 400 Hz excitation to position synchro (Pin 2)
D = Servovalve spool signal (Pin 11)
E & F = Strut position (Pins 9 & 10)
G = EHSV Current (Pin 12)

Figure 7. Test NOR Gate

For H to be high (non-failure); A, B, C, D, E, F, G <u>must all be low.</u>

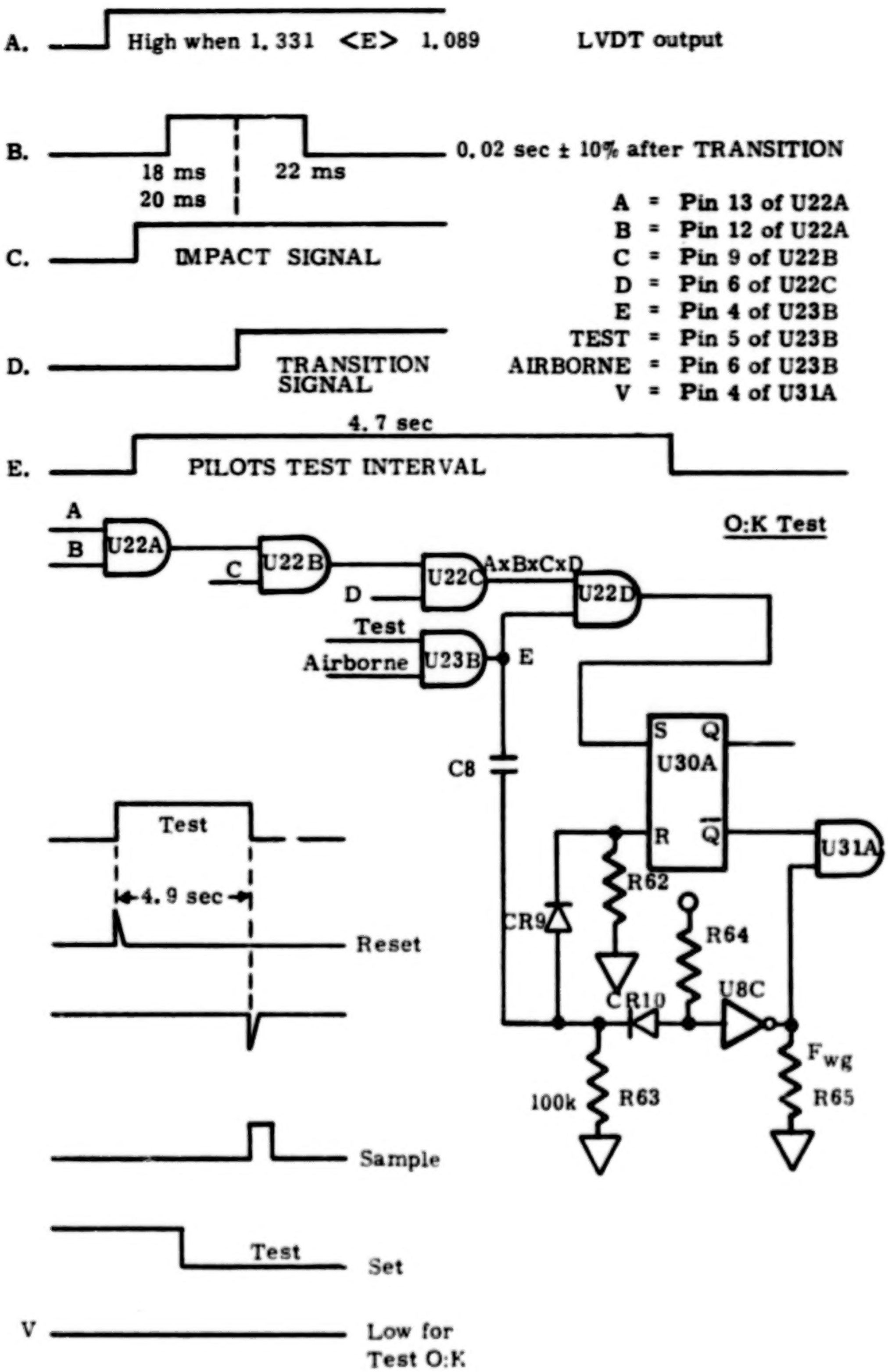


Figure 8. Test Input and Relative Timing

(6) U19 calculates the potential energy $(X_m - X_s) F_{wg}$ using $(X_m - X_s) = 0.5$ v and $F_{wg} = -0.3$ V.

(7) U13C compares KE to PE. Using the values of F_{wg} and $(X_m - X_s)$ given, the time for U13C to reach IMPACT is 1.625 seconds. Flip-flop U14B is SET to indicate IMPACT when PE $\geq$ KE.

(8) The high levels of U45B and U14B enable U25A which sets sample/hold amplifier U17 to hold the value of $F_{wg} = -0.3$ volts for calculation by U18 to develop $(F_{LC})^2$.

(9) U13A compares V_s (+10V) with $(F_{LC})^2 + V_{wg}$ from U7A and U18. U14A is SET when V_t is reached and the TRANSITION state is established. Sample/hold U17 is switched to the RAMP mode by the output of U8F.

(10) The time from IMPACT to TRANSITION is 2.285 sec for the test voltages applied.

(11) The value of $F_{wg} = -0.3$ V is equivalent to more than F_{min}. Therefore, the servo loop input is F_{LC} (rather than zero) since U24A is not switched.

(12) U34A is switched so that F_{wg} to the servo loop is zero.

(13) IMPACT flip-flop U14B has been SET so analog switch U27A is closed and the servo loop is closed as when landing and F_{wg} is greater than F_{min}.

(14) The servo loop has an input equivalent to $F_{LC} = -0.3$ V which begins to reduce at the rate of 4.902 V/sec, (445 kN/sec)(100 000 lb/sec), from the beginning of the TRANSITION period. The rate is determined by R46 and C6 as in normal operation.

(15) The servo loop operates with $F_{wg} = 0$ and the only feedback signal is from U32B representing the demodulated feedback from the LVDT pickup.

(16) The closed loop should present an output voltage at U32B of 1.21 V representing a displacement of 3.07×10^{-3} m (0.121 in). of the spool LVDT.

(17) The circuit in Figure 9 is designed to perform the test for dynamic performance of the system when the craft is airborne.

The coincidence of the LVDT voltage and the reference should occur a time of 0.02 sec $\pm$ 10% after the beginning of the TRANSITION mode.

Prior to the TRANSITION gate $E_o = 0$ since $E_{in} = -V$ diode and $i_1 = i_2$ (the diodes are identical) E_o is expressed as $15\ (1 - e^{-t/rc})$ where $r = R59 + R60$ and $c = C7$. When TRANSITION goes positive capacitor C begins to charge at $1/C \int idt$ but since $E_o << 15$ V then $E_o \cong it/C$.

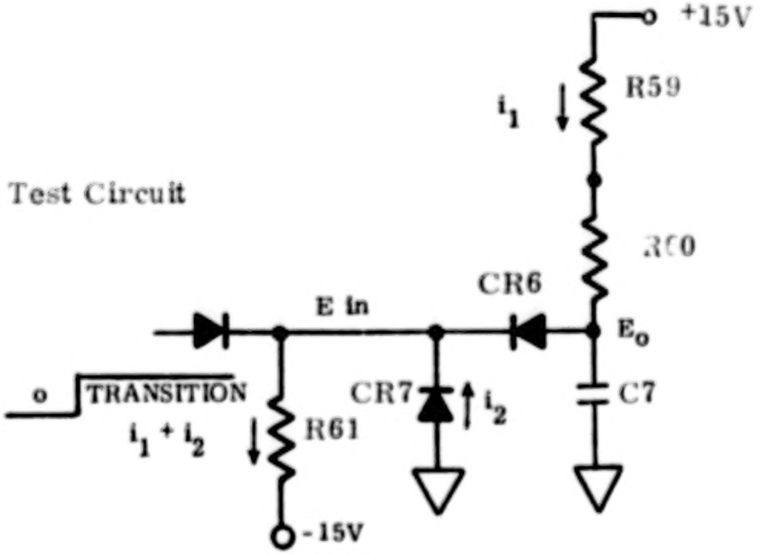
E_o reaches 1.21 V at about 1.21/15 = 8% of full charge so that the slope is reasonably linear at this point.

The charge is to reach 1.21 V in 0.02 sec, and C7=4.7 mfd, 5%, i = 284 mA.

Let r = 15V/0.3mA = 50K Ohms 1%, R60=10K Pot,
choose R61 =25K, 1%

V_C = 60.43 t volts or 1.2086 volt in 0.02 sec.

Figure 9. Airborne Test Circuit



(18) A failure can be indicated only during the TEST period which is 4.7 seconds in duration. This test is positive in nature since an OK test result must be achieved during the 4.7-second test or a failure is annunciated at the end of the test period. In effect, the flip-flop is RESET by the leading edge of the T[illegible] [illegible]erval. A SET toggle must be received from the OK test circuits during the 4.7 seconds or the still high state of the $\bar{Q}$ output will report the failure, since the sample pulse completes the AND for a high level output.

In Figure 10 , time and voltage are linear for a linear sawtooth so that the same reference can be used for the time gate and voltage limits of the test.

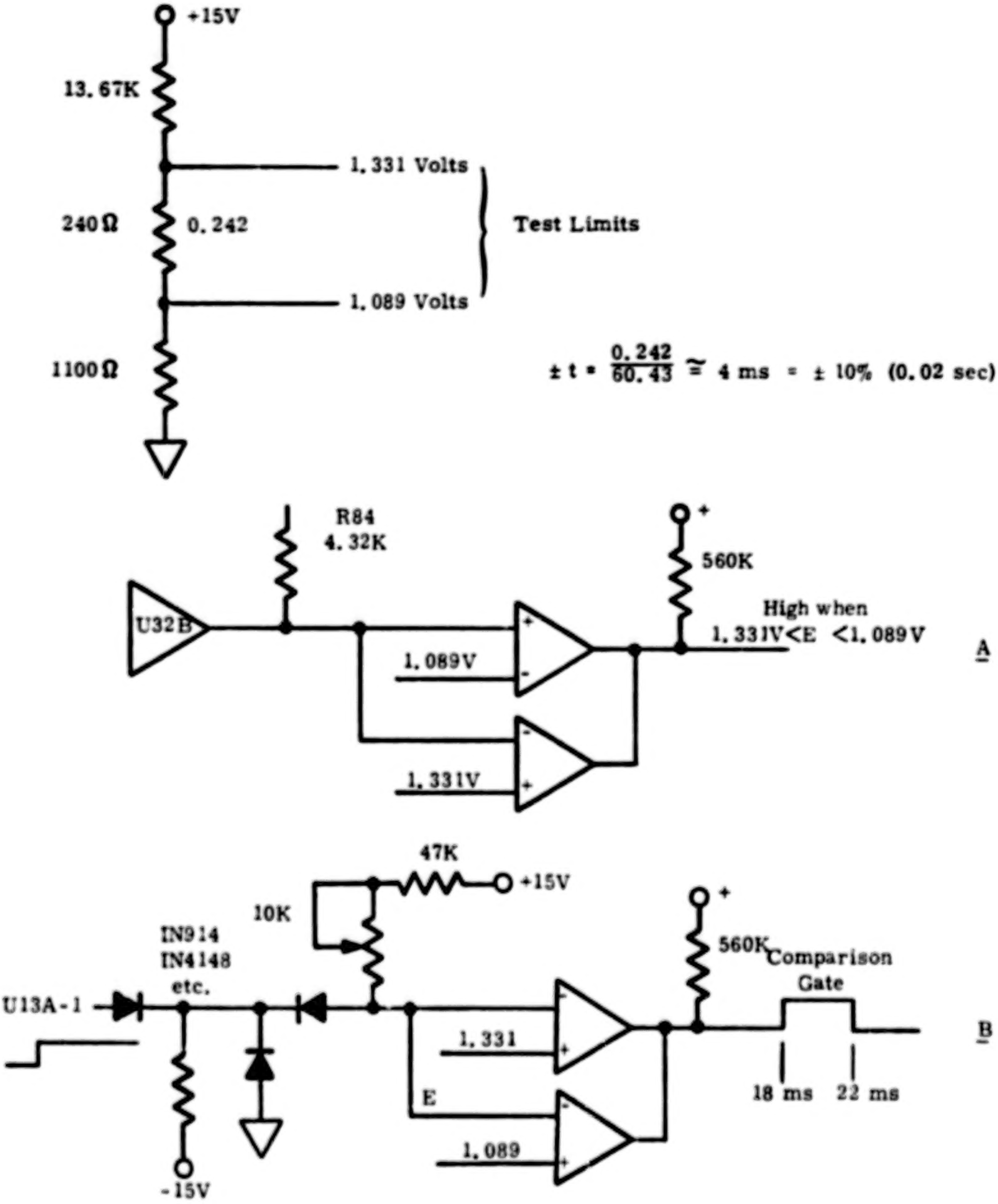


Figure 10. Test Circuit

(19) A successful OK test pulse must be developed in the circuits of paragraph (17) and can occur only after TRANSITION and IMPACT high levels are established. An intersect of the LVDT voltage must occur with 1.21 V ± 10% at a time of 0.02 sec ± 10% or an OK pulse cannot be generated.

(20) A successful dynamic test results in a TEST IN PROGRESS indication without a PASSIVE FAILURE indication following. At the conclusion of the test the TEST IN PROGRESS lamp will be extinguished.

(21) The AIRBORNE high level gate is AND'ed with the dynamic TEST gate to permit this test only during flight.

(22) A failure in either strut channel causes a signal to be applied through U1B, U8D, Q1 and Q2 of both channels to the solenoid valves of both channels thereby isolating the struts from the pressure source and causing reversion to a passive gear status.

X. SYSTEM SPECIFICATION

A complete system specification for a flightworthy electrohydraulic active control landing gear system for a supersonic airplane has been included as Appendix B.

XI. CONCLUDING REMARKS

The active control landing gear presented in this report is designed to be completely flightworthy and to meet all applicable military specifications. It contains the ability to detect failures and upon such failure to cause reversion to a passive configuration.

Two potential problems which have not been addressed are:

A. The effect of severe vibration at takeoff.

B. The possibility that on takeoff from an extremely uneven runway the strut may be depleted of fluid, causing the gas to fill the hydraulic chamber. Under these conditions the static design pressure will be lost.

XII. APPENDICES

The appendices are as follows:

A Stress Analysis

B System Specification

APPENDIX A

STRESS ANALYSIS

APPENDIX A

STRESS ANALYSIS

The following is the analysis of the Active Control Landing Gear, Dwg. No. 41004640. In all cases a conservative approach was taken. In the case of the Orifice Plate Support Assy, under every condition imaginable, the ΔP (internal & external) was very low; therefore, the ΔP which the structure was capable of withstanding was calculated and is summarized in the analysis. Load analysis of attachment hardware is also included.

Table Of Contents

Active Control Landing Gear

Table of Minimum Margins of Safety

PART NO.	DESCRIPTION	MATERIAL	LOADING CONDITION	MIN. M.S. YIELD	MIN. M.S. ULT	PAGES
41004818	Support Assy, orifice plate MLG.	321 CRES	To determine max. external & internal pressure assy can withstand	Max. ext. pressure =	1.324×10^4 KPa (1921 psi)	49-53
				Max. int. pressure =	1.602×10^4 KPa (2323 psi)	49-53
41004829-101 -102 -103 -104 -105 -106 -107 -108	Tube assys	21-6-9 CRES	Pressure & bending (-101, -104)	1.09	.98	54-57
			pressure (-102, -103, -107, -108)	2.26	1.21	54-56
			pressure (-105)	2.15	1.14	58-59
			pressure (-106)	2.12	1.11	59-61
41004819-001	Adapter	15-5 P_H CRES	Pressure	9.32	5.62	63
			pressure & moment (bolt)	----	1.51	64
			(lug)	----	1.21	65
41004819-007 -008	Servo valve brackets	6061-T6 alum sheet	Wt.& G loads: (tie-down bolts)	Large	Large	68-69
			(bracket bolts)	Large	Large	69-75
			(-007)	1.57 (tens)	----	75
			(-008)	Large (shear)	----	75
41004819-003 -004 -006	Accumulator clamps & brackets	7075-T7351	Wt.& G Loads: (thru bolt)	Large	Large	80
			(-003)	0.39	----	81-82
			(-004)	0.62	----	82-83
			(-006 bolts)	Large	----	83-86
			(-006 A/C load reqts)	2782 (tension) 746 (shear)	Per Attachment	86-87 86-87
			(-106 fitting)	.49	----	88-90

41004640 Landing Gear - Active Control

Material Properties

Tube Assys - 41004829 - CRES 21-6-9 Tubing per AMS5561

$F_{T_U} = 9.79\times10^5$ KPa (142 ksi) (min) .87*

$F_{T_Y} = 8.273\times10^5$ KPa (120 ksi) (min) .91*

ε (elongation) - 20% (min)

$E = 1.792\times10^8$ KPa (26×10^6 psi) .96*

$\rho = .286$

$G = 7.582\times10^7$ KPa (11×10^6 psi) .96*

(MIL-HDBK-5C, table 2.7.1.0 (b))

$\mu = .3$

Adapter - 41004819-001 - 15-5P_H CRES per AMS5659

$F_{T_U} = 1.069\times10^6$ KPa (155 ksi) (min) .92*

$F_{T_Y} = 9.986\times10^5$ KPa (145 ksi) .92*

$F_{C_Y} = 9.858\times10^5$ KPa (143 ksi) .90*

$F_{S_U} = 668.7$ KPa (97 ksi)

$E = 1.965\times10^8$ KPa (28.5×10^6 psi) .98*

$G = 7.721\times10^7$ KPa (11.2×10^6 psi) .98*

$\mu = .27$

$\rho = .283$

(MIL-HDBK-5C, table 2.6.7.0 (c))

*394°K (250°F) temp. factors

41004640 Landing Gear - Active Control

Material Properties (cont)

Manifold - 41004819-002; Clamps - 41004819-003, 0004, -005; Bracket - 41004819-006 (7075-T7351 AL ALY per QQ-A-250/12

F_{T_U} =	4.619×10^{5} KPa (67 ksi)	(min)	.82*	MIL-HDBK-5C, table 3.7.3.0 (b_2)
F_{T_Y} =	3.930×10^{5} KPa (57 ksi)	(min)	.85*	
F_{C_Y} =	3.861×10^{5} KPa (56 ksi)	(min)	.87*	
F_{S_U} =	2.6020×10^{5} KPa (38 ksi)	(min)	.91*	
E =	7.101×10^{6} KPa (10.3×10^{6} psi)		.92*	
G =	2.689×10^{7} KPa (3.9×10^{6} psi)		.92*	
μ =	.33			
ρ =	.101			

Brackets - 41004819-007, -008 - 6061-T6 AL sheet per QQ-A-250/11

F_{T_U} =	2.896×10^{5} KPa (42 ksi)	(min)	.86*	MIL-HDBK-5C, table 3.6.1.0 (b)
F_{T_Y} =	2.413×10^{5} KPa (35 ksi)	(min)	.88*	
F_{C_Y} =	2.413×10^{5} KPa (35 ksi)	(min)		
F_{S_U} =	1.861×10^{5} KPa (27 ksi)	(min)		

*394°K (250°F) temp. factors

41004640 Landing Gear - Active Control

Material Properties (cont)

Brackets - 41004819-007, -008 (cont)

E =	6.825×10^{7} KPa (9.9×10^{6} psi)	.97*	MIL-HDBK-5C, table 3.6.1.0 (b)
G =	2.620×10^{7} KPa (3.8×10^{6} psi)	.97*	
μ =	.33		
ρ =	.098		

Support - 41004818-001, -002 - 321 CRES bar per QQ-S-763, cond. A

F_{T_U} =	5.171×10^{5} KPa (75 ksi)	.87*	
F_{T_Y} =	2.068×10^{5} KPa (30 ksi)	.91*	
ε (elongation) = 40%			
γ (red. area) = 50%			
E =	1.999×10^{8} KPa (29×10^{6} psi)	.96*	MIL-HDBK-5C, table 2.7.1.0 (b)
G =	8.618×10^{7} KPa (12.5×10^{6} psi)	.96*	
μ =	.3		
ρ =	.286		
F_{C_Y} =	1.861×10^{5} KPa (27 ksi)	.95*	
F_{S_U} =	3.447×10^{5} KPa (50 ksi)	.84*	

*394°K (250°F) temp. factors

41004640 Landing Gear - Active Control

Material Properties (cont)

Support - 41004818-003 - 321CRES sheet per MIL-S-6721, comp TI

MIL-HDBK-5C, table 2.7.1.0 (b):

F_{T_U} =	6.894×10^5 KPa (100 ksi) (max) 5.171×10^5 KPa (75 ksi) (min)	.87*
F_{T_Y} =	2.068×10^5 KPa (30 ksi)	.91*
F_{C_Y} =	1.861×10^5 KPa (27 ksi)	.95*
F_{S_U} =	3.447×10^5 KPa (50 ksi)	.84*
E =	1.999×10^8 KPa (29×10^6 psi)	.96*
G =	8.618×10^7 KPa (12.5×10^6 psi)	.96*
μ =	.3	
ρ =	.286	

Tube 41004818-004 - 321 CRES tube per MIL-T-8808, type 1

F_{T_U} = 6.894×10^5 KPa (100 ksi) (max) (MIL-T-8808)

MIL-HDBK-5C, table 2.7.1.0 (b):

F_{T_U} =	5.171×10^5 KPa (75 ksi) (min)	.87*
F_{T_Y} =	2.068×10^5 KPa (30 ksi) (min)	.91*
F_{C_Y} =	1.861×10^5 KPa (27 ksi) (min)	.95*

*394°K (250°F) temp. factors

41004640 Landing Gear - Active Control

Material Properties (cont)

Tube 41004818-004 (cont)

F_{S_U} =	3.447×10^5 KPa (50 ksi) (min)	.84*	MIL-HDBK-5C, table 2.7.1.0 (b)
E =	1.999×10^8 KPa (29×10^6 psi)	.96*	
G =	8.618×10^7 KPa (12.5×10^6 psi)	.96*	
μ =	.3		
ρ =	.286		

*394°K (250°F) temp. factors

Design Criteria

System Limit Pressure = 1.517×10^4 KPa (2200 psi)

System Proof Pressure = 1.5 x limit pressure
System Burst Pressure = 2.5 x limit pressure

G_{FWD} = 1.5 G_{UP} = 2.1 G_{INBD} = 1.5

G_{AFT} = 1.5 G_{DOWN} = 5.85 G_{OUTBD} = 1.5

Data from aircraft manufacturer (Flight Ult. 'G' Loads)

41004640 - Landing Gear, Active Control

Weights of Parts

No. Req'd	Description	Part Number	Weight N (lb)	Weight Per Side N (lb)
1	Adapter (2)	41004819-001	19.17 (4.31)	19.17 (4.31)
1	Manifold (3)	41004819-002	34.43 (7.74)	34.43 (7.74)
2	Clamp (4)	41004819-003	7.295 (1.64)	14.59 (3.28)
2	Clamp (5)	41004819-101	15.66 (3.52)	31.31 (7.04)
2	Clamp (6)	41004819-005	4.048 (.91)	8.095 (1.82)
4	Bracket (7)	41004819-006	1.601 (.36)	6.405 (1.44)
2	Bracket (8)	41004819-007	.667 (.15)	1.334 (.30)
1	Bracket (9)	41004819-008	1.824 (.41)	1.824 (.41)
3	Pipe assy (10)	41004829-101	3.603 (.81)	11.03 (2.43)
1	Pipe assy (11)	41004829-102	4.893 (1.10)	4.893 (1.10)
1	Pipe assy (12)	41004829-103	5.738 (1.29)	5.738 (1.29)
1	Pipe assy (13)	41004829-104	4.581 (1.03)	4.581 (1.03)
4	Pipe assy (14)	41004829-105	2.269 (.51)	9.074 (2.04)
1	Pipe assy (15)	41004829-106	7.072 (1.59)	7.072 (1.59)
1	Pipe assy (16)	41004829-107	17.75 (3.99)	17.75 (3.99)
1	Servo valve (17)	23241830	117.9 (26.5)	117.9 (26.5)
1	Relief valve(18)	5130T-16TT-2000	6.005 (1.35)	6.005 (1.35)
1	Bracket (19)	41004819-009	.311 (.07)	.311 (.07)
1	Valve, sol. oper. shutoff, R.H. (20) Valve, sol. oper. shutoff, L.H. (22)	25200 (HRT) 25450 (HRT)	22.24 (5.00)	22.24 (5.00)
4	Accumulator (empty) (21)	MS28797-7	111.2 (25.0	444.8 (100.00)
4	Plug (23)	AN814-12	.979 (.22)	3.914 (.88)

41004640 - Landing Gear, Active Control

Weights of Parts (cont)

No. Req'd	Description	Part Number	Weight N (lb)	Weight Per Side N (lb)
1	Plug (24)	AN814-16	1.423 (.32)	1.423 (.32)
2	Plug (25)	AN814-20	1.957 (.44)	3.914 (.88)
4	Union (26)	AN815-12	1.423 (.32)	5.693 (1.28)
4	Union (27)	AN815-16	2.135 (.48)	8.540 (1.92)
2	Tee (28)	AN824-16	4.315 (.97)	8.629 (1.94)
1	Check valve (29)	2C6510 (Crissair)	1.112 (.25)	1.112 (.25)
3	Reducer (30)	AN919-26	2.669 (.60)	8.006 (1.80)
1	Pipe assy (31)	41004829-108	5.338 (1.20)	5.338 (1.20)
12	Bolt (38)	NAS1224C1	.0534 (.012)	.667 (.15)
4	Bolt (39)	NAS1228C1	.325 (.073)	1.290 (.29)
16	Bolt (40)	NAS1226C6	.1868 (.042)	2.980 (.67)
4	Bolt (41)	NAS1228C132	2.344 (.527)	9.385 (2.11)
4	Bolt (42)	NAS1351C4H12	.0623 (.014)	.267 (.06)
2	Bolt (43)	NAS1224C32	.165 (.037)	.31[illegible] (.07)
4	Nut (44)	AN315C4R	.0311 (.007)	.133 (.03)
2	Bolt (48)	NAS1223C1	.0267 (.006)	.0445 (.01)

Total Per Side (empty assy) 830.0N (186.59 lbs)

Total Per Side (accumulators full) 1042N (234.27 lbs)

41004640 - Landing Gear, Active Control

41004818 - Support Assy, Orifice Plate, MLG

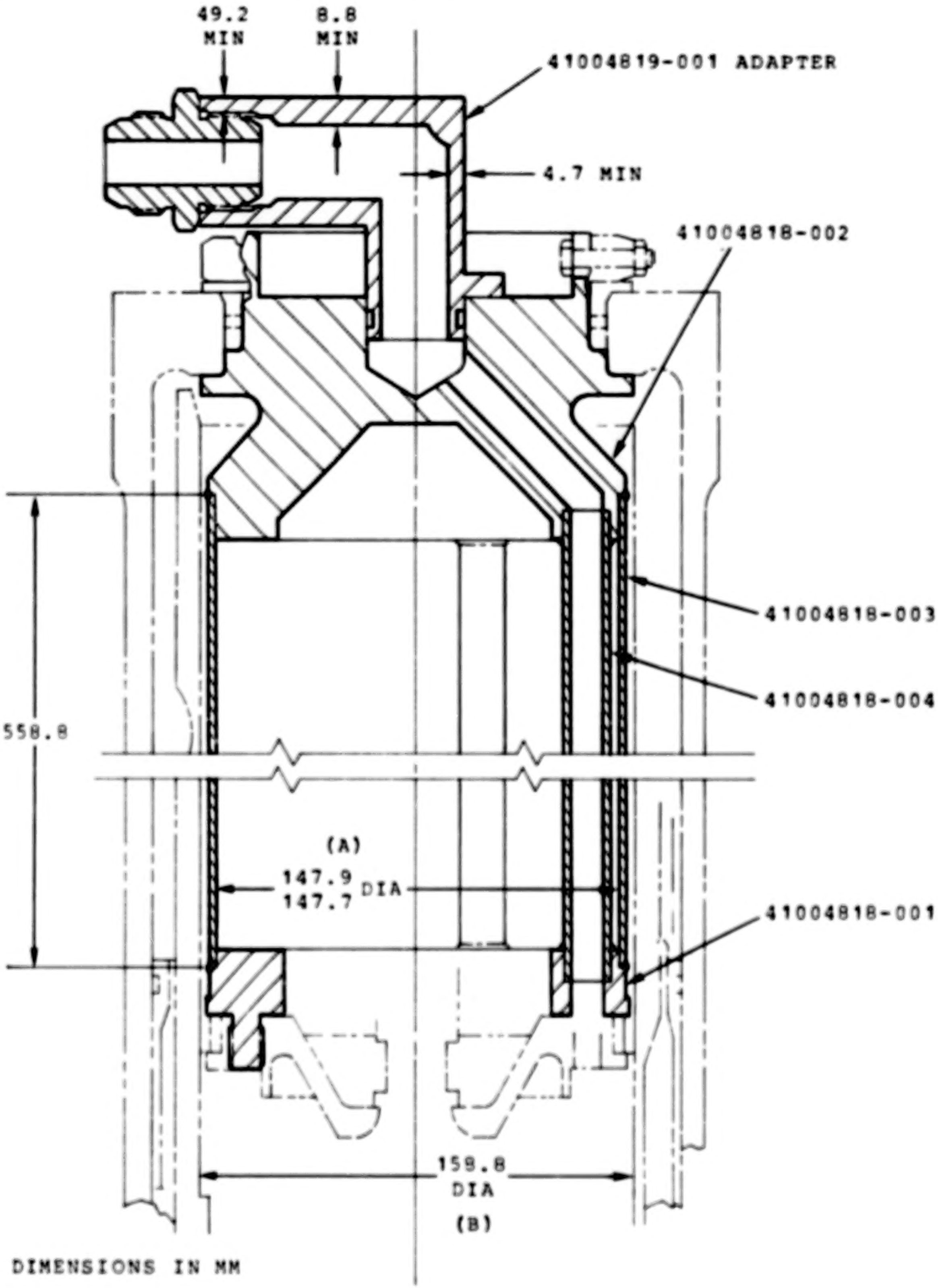


Figure A-1. Orifice Plate Support Assembly

41004640 - Landing Gear, Active Control

41004818 - Support Assy, Orifice Plate, MLG (cont)

Based on the System design, the Δp between chamber (A) and chamber (B) (see Fig A-1) is always very small unless the servo valve is either not working or has been shut off. If this is the case, any tension or compression loads on the Orifice Plate Support Assy are very small. Therefore, it has been decided to determine the max. Δp the assembly can withstand in either direction before yielding of the material (since material is 321 stainless, cond. A which has a yield allowable of only 40% of ultimate allowable).

Case 1 - Compression Load in Cylinder (pressure in (B) > pressure in (A)

Determine max. Δp in (B) over (A)

Length (cyl. wall & 6 tubes) $= \ell = \begin{matrix} 0.559\text{M} \\ (22.00 \text{ in}) \end{matrix}$

$$r(\text{rad. of gyr.-cyl.}) = \frac{1}{4}\sqrt{D_o^2 + D_i^2} = \frac{1}{4}\sqrt{(6.05)^2 + (5.825)^2} = 2.0996$$

$$\frac{\ell}{r}(\text{cyl}) = 10.47819$$

$$r(\text{rad. of gyr.-tube}) = \frac{1}{4}\sqrt{D_o^2 + D_i^2} = \frac{1}{4}\sqrt{.620^2 + .503^2} = .19959$$

$$\frac{\ell}{r}(\text{tube}) = 110.22334$$

$$\sigma_{cr} = K\frac{\pi^2 E}{(\frac{\ell}{r})^2} \text{ (for elastic buckling) where K (fixed gnds) = 4}$$

$$E = (29\times10^6)(.96) = \begin{matrix} 1.919\times10^8\,\text{KPa} \\ (27.84\times10^6 \text{ psi}) \end{matrix}$$

$$\sigma_{cr} = 4\frac{\pi^2(27.84\times10^6)}{(10.47819)^2} = \begin{matrix} 6.901\times10^7\,\text{KPa} \\ (10{,}010{,}515 \text{ psi})(\text{main cyl}) \end{matrix}$$

$$\sigma_{cr} = 4\frac{\pi^2(27.84\times10^6)}{(110.22334)^2} = \begin{matrix} 6.237\times10^5\,\text{KPa} \\ (90465 \text{ psi}) \text{ (tubes)} \end{matrix}$$

Based on the above $\sigma_{cr} = F_{cy}$ for cyl & tubes

41004640 - Landing Gear, Active Control

41004818 - Support Assy, Orifice Plate, MLG (cont)

Case 1 - Compression Load in Cylinder (cont)

$$F_{cy}(\text{main cyl})=27000(.95)=\begin{matrix}1.768\times10^{5}\text{KPa}\\(25650\text{ psi})\end{matrix}$$

$$F_{cy}(\text{tubes})=27000(.95)=\begin{matrix}1.768\times10^{5}\text{KPa}\\(25650\text{ psi})\end{matrix}$$

$$A(\text{main cyl})=\pi Dt=\pi\left[\frac{6.05+5.825}{2}\right](.090)=\begin{matrix}.00108\text{M}^2\\(1.67879\text{ in}^2)\end{matrix}$$

$$A(\text{tubes})=6\left[\frac{\pi}{4}(.620^2-.503^2)\right]=\begin{matrix}3.995\times10^{-4}\text{M}^2\\(.61917\text{ in}^2)\end{matrix}$$

$$P_{YIELD}(\text{main tubes})=(25650)(1.67879)=\begin{matrix}1.915\times10^{5}\text{N}\\(43061\text{ lb})\end{matrix}$$

$$P_{YIELD}(\text{tubes})=(25650)(.61917)=\begin{matrix}7.064\times10^{4}\text{N}\\(15882\text{ lb})\end{matrix}$$

$$P_{YIELD}(\text{total})=43061+15882=\begin{matrix}2.622\times10^{5}\text{N}\\(58943\text{ lb})\end{matrix}$$

$$\Delta P(\text{Pressure (B)}>\text{Pressure (A)})=\frac{58943}{\frac{\pi}{4}(6.25)^2}=\begin{matrix}1.324\times10^{4}\text{KPa}\\\underline{(1921\text{ psi})}\end{matrix}$$

Case 2 - Tension Load in Cylinder (Pressure in (A)>Pressure in (B)
Cylinder Wall & Tubes

$$A(\text{main cyl})=\begin{matrix}.00108\text{M}^2\\(1.67879\text{ in}^2)\end{matrix}$$

$$A(\text{tubes})=\begin{matrix}3.995\times10^{-4}\text{M}^2\\(.61917\text{ in}^2)\end{matrix}$$

$$F_{ty}(\text{main cyl})=30000(.91)=\begin{matrix}1.882\times10^{5}\text{KPa}\\(27300\text{ psi})\end{matrix}$$

41004640 - Landing Gear, Active Control

41004818 - Support Assy, Orifice Plate, MLG (cont)

Case 2 - Tension Load in Cylinder (cont)

Cylinder Wall & Tubes

$F_{ty}(\text{tubes}) = 30000(.91) = \dfrac{1.882\times10^5 \text{ KPa}}{(27300 \text{ psi})}$

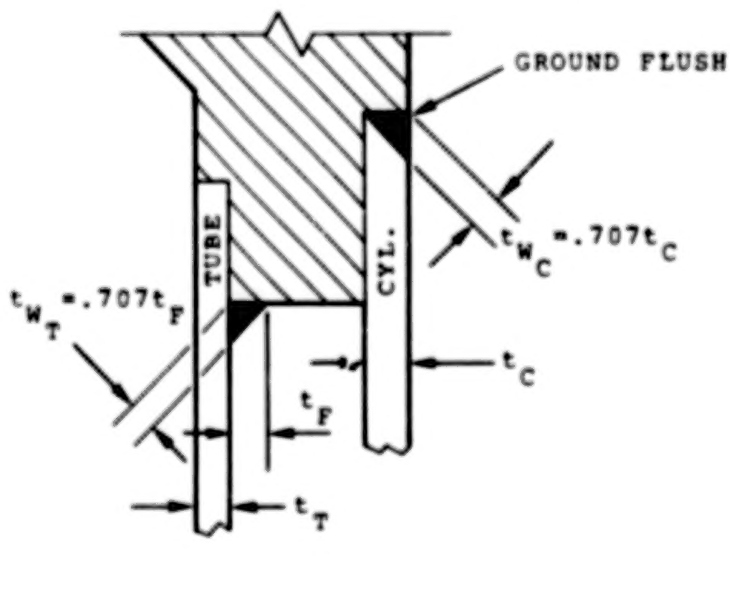
$P_{YIELD}(\text{main cyl}) = (27300)(1.6789) = \dfrac{2.039\times10^5 \text{ N}}{(45831 \text{ lb})}$

$P_{YIELD}(\text{tubes}) = (27300)(.61917) = \dfrac{7.521\times10^4 \text{ N}}{(16903 \text{ lb})}$

$P_{YIELD}(\text{total}) = 45831 + 16903 = \dfrac{2.790\times10^5 \text{ N}}{(62734 \text{ lb})}$

$\Delta p(\text{Pressure (A)} > \text{Pressure (B)}) = \dfrac{62734}{\frac{\pi}{4}(5.825)^2} = \dfrac{1.623\times10^4 \text{ KPa}}{(2354 \text{ psi})}$

WELDS IN SHEAR (CYL. & TUBES)



41004818 - Support Assy, Orifice Plate, MLG (cont)

Case 2 - Tension Load in Cylinder (cont)
Cylinder Wall & Tubes

$t_c = .090$

$t_f = .063$ min

K(weld factor)=.85 (MIL-HDBK-5C)

$F_{S_U}(\text{main cyl}) = (50000)(.84) = \genfrac{}{}{0pt}{}{2.896\times10^5\,\text{KPa}}{(42000\text{ psi})}$

$F_{S_U}(\text{tubes}) = (50000)(.84) = \genfrac{}{}{0pt}{}{2.896\times10^5\,\text{KPa}}{(42000\text{ psi})}$

$A_{S_H}(\text{main cyl}) = \pi\left[\frac{6.05 + 5.825}{2}\right](.707)(.090) = \genfrac{}{}{0pt}{}{7.658\times10^{-4}\,\text{M}^2}{(1.18690\text{ in}^2)}$

$A_{S_H}(\text{tubes}) = 6(\pi)\left[.620 + \frac{.063}{2}\right](.707)(.063) = \genfrac{}{}{0pt}{}{3.529\times10^{-4}\,\text{M}^2}{(.54699\text{ in}^2)}$

$P_{SHEAR}(\text{main cyl}) = (42000)(.85)(1.1869) = \genfrac{}{}{0pt}{}{1.885\times10^5\,\text{N}}{(42372\text{ lb})}$

$P_{SHEAR}(\text{tubes}) = (42000)(.85)(.54699) = \genfrac{}{}{0pt}{}{8.686\times10^4\,\text{N}}{(19528\text{ lb})}$

$P_{SHEAR}(\text{total}) = 42372 + 19528 = \genfrac{}{}{0pt}{}{2.753\times10^5\,\text{N}}{(61900\text{ lb})}$

$\Delta p(\text{Pressure (A)} > \text{Pressure (B)}) = \frac{61900}{\frac{\pi}{4}(5.825)^2} = \genfrac{}{}{0pt}{}{1.602\times10^4\,\text{KPa}}{\underline{\underline{(2323\text{ psi})}}}$

Summary - Max Pressures Support Can Withstand

Max Ext Pressure (Pressure in (B)>Pressure in (A))	1.324×10^4 KPa (1921 psi)
Max Int Pressure (Pressure in (A)>Pressure in (B))	1.602×10^4 KPa (2323 psi)

41004640 - Landing Gear, Active Control

Tube Analysis

(1.00 dia tube) $O.D._{min} = \begin{matrix}.0254M \\ (1.00 \text{ in})\end{matrix}$

$I.D._{max} = 1.00-2(.052-.005) = \begin{matrix}.0230M \\ (.906 \text{ in})\end{matrix}$

(.75 dia tube) $O.D._{min} = \begin{matrix}.01905M \\ (.750 \text{ in})\end{matrix}$

$I.D._{max} = .750-2(.039-.005) = \begin{matrix}.01732M \\ (.682 \text{ in})\end{matrix}$

(.625 dia tube) $O.D._{min} = \begin{matrix}.0159M \\ (.625 \text{ in})\end{matrix}$

$I.D._{max} = .625-2(.033-.005) = \begin{matrix}.01445M \\ (.569 \text{ in})\end{matrix}$

$$\frac{R_{max}}{t_{min}} = \frac{.5015}{.047} = 10.67 \qquad = \frac{.3765}{.034} = 11.07 \qquad = \frac{.314}{.028} = 11.21$$

Since these tubes are borderline between thinwall and thickwall, use thick wall analysis (Roark, 4th Ed., Table XIII, Case 35, P. 308).

Tube Assys 41004829-101, -102, -103, -104, -107, -108

$$\sigma_{\ell} = p\frac{a^2}{b^2-a^2} \quad \text{where} \quad a_{max} = \frac{.906}{2} = \begin{matrix}.01151M \\ (.453 \text{ in})\end{matrix}$$

$$b_{min} = \frac{1.00}{2} = \begin{matrix}.0127M \\ (.500 \text{ in})\end{matrix}$$

$$p = \begin{matrix}1.517\times10^4 KPa \\ (2200 \text{ psi})\end{matrix}$$

$$\sigma_{\ell} = 2200\frac{.453^2}{.500^2-.453^2} = \begin{matrix}6.949\times10^4 KPa \\ \underline{(10079 \text{ psi})}\end{matrix}$$

$$\sigma_H = p\frac{b^2+a^2}{b^2-a^2} = \frac{(2200)(.500^2+.453^2)}{.500^2-.453^2} = \begin{matrix}1.541\times10^5 KPa \\ \underline{(22359 \text{ psi})}\end{matrix}$$

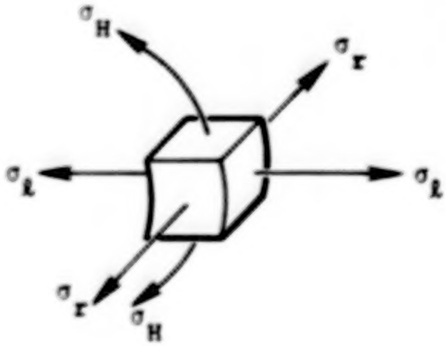
41004640 - Landing Gear, Active Control

Tube Analysis (cont)
Tube Assys 41004829-101, -102, -103, -104, -107, -108 (cont)

$\sigma_r = -p = \begin{matrix} -1.517\times10^4 \text{KPa} \\ (-2200 \text{ psi}) \end{matrix}$

$\tau = p\dfrac{b^2}{b^2-a^2} = (2200)\dfrac{.500^2}{.500^2-.453^2} = \begin{matrix} 8.465\times10^4 \text{KPa} \\ \underline{(12279 \text{ psi})} \end{matrix}$

$\sigma_\ell(\text{proof}) = 10079\times1.5 = \begin{matrix} 1.042\times10^5 \text{KPa} \\ (15119 \text{ psi}) \end{matrix}$



$\sigma_H(\text{proof}) = 22359\times1.5 = \begin{matrix} 2.312\times10^5 \text{KPa} \\ (33539 \text{ psi}) \end{matrix}$

$\sigma_r(\text{proof}) = -2200\times1.5 = \begin{matrix} -2.275\times10^4 \text{KPa} \\ (-3300 \text{ psi}) \end{matrix}$

$\tau(\text{proof}) = 12279\times1.5 = \begin{matrix} 1.270\times10^5 \text{KPa} \\ \underline{(18419 \text{ psi})} \end{matrix}$

$\sigma_E(\text{equiv. stress theory}) = .707\sqrt{(\sigma_\ell-\sigma_H)^2+(\sigma_H-\sigma_r)^2+(\sigma_r-\sigma_\ell)^2}$ (Bruhn, P. C1.9)

$\sigma_E = .707\sqrt{(15119-33539)^2+(33539+3300)^2+(-3300-15119)^2} = \begin{matrix} 2.199\times10^5 \text{KPa} \\ \underline{\underline{(31899 \text{ psi})}} \end{matrix}$ (proof)

$\left.\begin{matrix} \text{M.S.}_{\text{YIELD}} = \dfrac{120000(.91)}{31899} - 1 = \boxed{2.42} \\ \\ \text{M.S.}_{\substack{\text{SHEAR} \\ \text{YIELD}}} = \dfrac{(.55)(120000)(.91)}{18419} - 1 = \boxed{2.26} \end{matrix}\right\}$ (pressure only)

$\sigma_\ell(\text{burst}) = 10079\times2.5 = \begin{matrix} 1.737\times10^5 \text{KPa} \\ (25198 \text{ psi}) \end{matrix}$

$\sigma_H(\text{burst}) = 22359\times2.5 = \begin{matrix} 3.854\times10^5 \text{KPa} \\ (55898 \text{ psi}) \end{matrix}$

$\sigma_r(\text{burst}) = -2200\times2.5 = \begin{matrix} -3.792\times10^4 \text{KPa} \\ (-5500 \text{ psi}) \end{matrix}$

Tube Analysis (cont)

Tube Assys 41004829-101, -102, -103, -104, -107, -108 (cont)

$$\tau(\text{burst}) = 12279 \times 2.5 = \begin{matrix} 2.116 \times 10^5 \text{ KPa} \\ \underline{\underline{(30698 \text{ psi})}} \end{matrix}$$

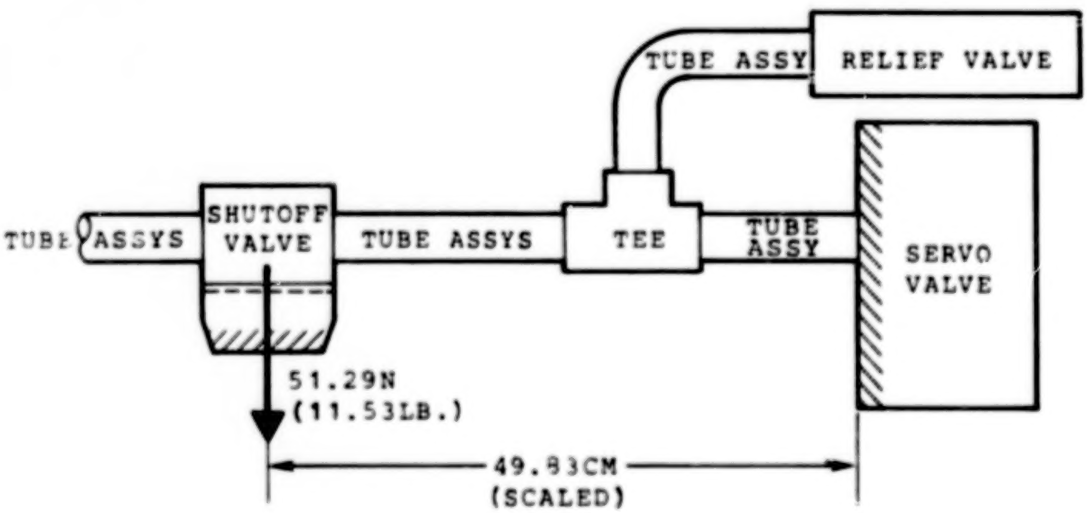
$$\sigma_E = .707\sqrt{(25198-55898)^2 + (55898+5500)^2 + (-5500-25198)^2} = \begin{matrix} 3.665 \times 10^5 \text{ KPa} \\ \underline{\underline{(53164 \text{ psi})}} \end{matrix}$$

$$\left.\begin{aligned} M.S._{ULT} &= \frac{142000(.87)}{53164} - 1 = \boxed{1.32} \\ M.S._{\substack{SHEAR\\ULT}} &= \frac{(.55)(142000)(.87)}{30698} - 1 = \boxed{1.21} \end{aligned}\right\} \text{(pressure only)}$$

Bending of 41004829-101

Assume no support on tube assys from servo valve to Aircraft Pressure Return System. Let total weight be assumed at ℄ shutoff valve and reacted in bending by above tube assy. (very conservative).

$$\text{Total Wt} = 5.00 + .48 + 1.03 + .97 + 1.29 + 1.35 + .81 + .60 = \begin{matrix} 51.29\text{N} \\ \underline{(11.53 \text{ lb})} \end{matrix}$$



$$I(\text{tube}) = \frac{\pi}{4}\left[.500^4 - .453^4\right] = \begin{matrix} 6.664 \times 10^{-9} \text{ M}^4 \\ (.016014 \text{ in}^4 \end{matrix}$$

41004640 - Landing Gear, Active Control

Tube Analysis (cont)
Bending of 41004829-101 (cont)

$C = \genfrac{}{}{0pt}{}{.0127M}{(.500\ in)}$ 'G' factor (vert. down)=5.85 g

$M = (11.53)(5.85)(19.62) = \genfrac{}{}{0pt}{}{149.5N\text{-}M}{(1323.3788\ in/lb)}$

$\sigma_b = \frac{(1323.3788\ in/lb)(.500)}{.016014} = \genfrac{}{}{0pt}{}{2.849\times10^5 KPa}{\underline{(41319\ psi)}}$ $\tau = \frac{(11.53)(5.85)}{\frac{\pi}{4}(1.00^2 - .906^2)} = \genfrac{}{}{0pt}{}{3302KPa}{\underline{(479\ psi)}}$

Total $\sigma_\ell = 41319 + 15119 = \genfrac{}{}{0pt}{}{3.891\times10^5 KPa}{(56438\ psi)\ (proof)}$ Total $\tau = 18419 + 479 = \genfrac{}{}{0pt}{}{1.303\times10^5 KPa}{\underline{(18898\ psi)}\ (proof)}$

$= 41319 + 25198 = \genfrac{}{}{0pt}{}{4.586\times10^5 KPa}{(66517\ psi)\ (burst)}$ $= 30698 + 479 = \genfrac{}{}{0pt}{}{2.149\times10^5 KPa}{\underline{(31177\ psi)}\ (burst)}$

$$\sigma_E = .707\sqrt{(56438-33539)^2 + (33539+3300)^2 + (-3300-56438)^2} = \genfrac{}{}{0pt}{}{3.598\times10^5 KPa}{\underline{(52194\ psi)}}$$
(proof & 5.85 g bending)

$$\left.\begin{array}{l} M.S._{YIELD} = \frac{120000(.91)}{52194} - 1 = \boxed{1.09} \\ \\ M.S._{\substack{SHEAR\\YIELD}} = \frac{(.55)(120000)(.91)}{18898} - 1 = \boxed{2.18} \end{array}\right\}\text{(proof pressure \& bending)}$$

$$\sigma_E = .707\sqrt{(66517-33539)^2 + (33539+5500)^2 + (-5500-66517)^2} = \genfrac{}{}{0pt}{}{4.304\times10^5 KPa}{\underline{(62433\ psi)}}$$
(burst & 5.85 g bending)

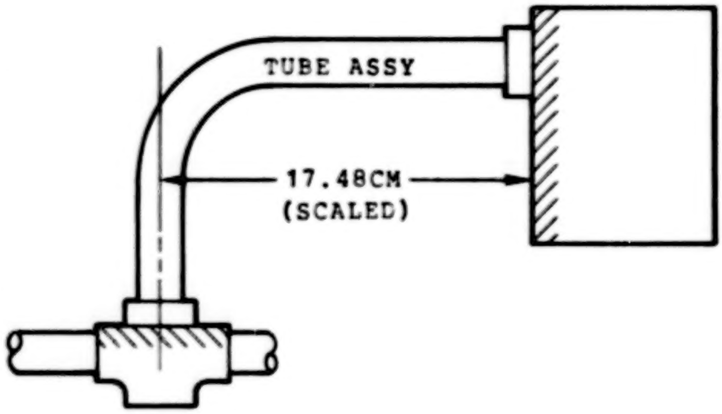
$$\left.\begin{array}{l} M.S._{ULT} = \frac{142000(.87)}{62433} - 1 = \boxed{.98} \\ \\ M.S._{\substack{SHEAR\\ULT}} = \frac{(.55)(142000)(.87)}{31177} - 1 = \boxed{1.18} \end{array}\right\}\text{(burst pressure \& bending)}$$

41004640 - Landing Gear, Active Control

Tube Analysis (cont)
Bending of 41004829-104

Assume all parts from servo valve to manifold have their C.G. at ℄ of shutoff valve and are reacted in bending by above tube assy. (very conservative).

Total Wt=.60+1.20+.48= $\frac{10.14\text{N}}{(2.28\text{ lb})}$



M=(9.02)(5.85)(6.88)

= $\frac{41.02\text{N-M}}{(363.037\text{ in/lb})}$

Since moment is less than -101↑ and tube is same diameter & thickness, further analysis is unnecessary.

Tube Assy 41004829-105

$p = \frac{1.517\times10^{4}\text{ KPa}}{(2200\text{ psi})}$ $\quad a_{max} = \frac{.682}{2} = \frac{.00866\text{M}}{(.341\text{ in})}$

$b_{min} = \frac{.750}{2} = \frac{.00953\text{M}}{(.375\text{ in})}$

$$\sigma_{\ell}(\text{limit}) = (2200)\frac{.341^2}{.375^2-.341^2} = \frac{7.244\times10^{4}\text{ KPa}}{(10508\text{ psi})}$$

$$\sigma_{H}(\text{limit}) = (2200)\frac{.375^2+.341^2}{.375^2-.341^2} = \frac{1.601\times10^{5}\text{ KPa}}{(23217\text{ psi})}$$

$$\sigma_{r}(\text{limit}) = \frac{-1.517\times10^{4}\text{ KPa}}{(-2200\text{ psi})}$$

$$\tau(\text{limit}) = (2200)\frac{.375^2}{.375^2-.341^2} = \frac{8.761\times10^{4}\text{ KPa}}{(12708\text{ psi})}$$

$$\sigma_{\ell}(\text{proof}) = 10508\times1.5 = \frac{1.087\times10^{5}\text{ KPa}}{(152762\text{ psi})}$$

$$\sigma_{H}(\text{proof}) = 23217\times1.5 = \frac{2.401\times10^{5}\text{ KPa}}{(34826\text{ psi})}$$

41004640 - Landing Gear, Active Control

Tube Analysis (cont)
Tube Assy 41004829-105 (cont)

$$\sigma_r\,(\text{proof}) = -2200 \times 1.5 = \begin{array}{l} 2.275 \times 10^4\ \text{KPa} \\ (-3300\ \text{psi}) \end{array}$$

$$\tau\,(\text{proof}) = 12708 \times 1.5 = \begin{array}{l} 1.314 \times 10^5\ \text{KPa} \\ \underline{\underline{(19062\ \text{psi})}} \end{array}$$

$$\sigma_E = .707\sqrt{(15762-34826)^2 + (34826+3300)^2 + (-3300-15762)^2} = \begin{array}{l} 2.276 \times 10^5\ \text{KPa} \\ \underline{\underline{(33013\ \text{psi})}} \end{array}$$

$$\left.\begin{array}{l} \text{M.S.}_{\text{YIELD}} = \dfrac{120000(.91)}{33013} - 1 = \boxed{2.31} \\[2ex] \text{M.S.}_{\substack{\text{SHEAR} \\ \text{YIELD}}} = \dfrac{(.55)(120000)(.91)}{19062} - 1 = \boxed{2.15} \end{array}\right\} \text{(proof pressure only)}$$

$$\sigma_\ell\,(\text{burst}) = 10508 \times 2.5 = \begin{array}{l} 1.811 \times 10^5\ \text{KPa} \\ (26770\ \text{psi}) \end{array}$$

$$\sigma_H\,(\text{burst}) = 23217 \times 2.5 = \begin{array}{l} 4.002 \times 10^5\ \text{KPa} \\ (58043\ \text{psi}) \end{array}$$

$$\sigma_r\,(\text{burst}) = -2200 \times 2.5 = \begin{array}{l} -3.792 \times 10^4\ \text{KPa} \\ (-5500\ \text{psi}) \end{array}$$

$$\tau\,(\text{burst}) = 12708 \times 2.5 = \begin{array}{l} 2.190 \times 10^5\ \text{KPa} \\ \underline{\underline{(31770\ \text{psi})}} \end{array}$$

$$\sigma_E = .707\sqrt{(26270-58043)^2 + (58043+5500)^2 + (-5500-26270)^2} = \begin{array}{l} 3.793 \times 10^5\ \text{KPa} \\ \underline{\underline{(55022\ \text{psi})}} \end{array}$$

$$\left.\begin{array}{l} \text{M.S.}_{\text{ULT}} = \dfrac{142000(.87)}{55022} - 1 = \boxed{1.25} \\[2ex] \text{M.S.}_{\substack{\text{SHEAR} \\ \text{ULT}}} = \dfrac{(.55)(142000)(.87)}{31770} - 1 = \boxed{1.14} \end{array}\right\} \text{(burst pressure only)}$$

41004640 - Landing Gear, Active Control

Tube Analysis (cont)
Tube Assy 41004829-106

$p = \begin{matrix} 1.517\times10^{4}\,\text{KPa} \\ (2200\ \text{psi}) \end{matrix}$ $\quad a_{max} = \dfrac{.569}{2} = \begin{matrix} .00723\text{M} \\ (.2845\ \text{in}) \end{matrix}$

$b_{min} = \dfrac{.625}{2} = \begin{matrix} .00794\text{M} \\ (.3125\ \text{in}) \end{matrix}$

$$\sigma_\ell(\text{limit}) = (2200)\frac{.2845^2}{.3125^2 - .2845^2} = \begin{matrix} 7.344\times10^{4}\,\text{KPa} \\ \underline{(10653\ \text{psi})} \end{matrix}$$

$$\sigma_H(\text{limit}) = 2200\ \frac{.3125^2 + .2845^2}{.3125^2 - .2845^2} = \begin{matrix} 1.620\times10^{5}\,\text{KPa} \\ \underline{(23505\ \text{psi})} \end{matrix}$$

$$\sigma_r\ (\text{limit}) = \begin{matrix} -1.517\times10^{4}\,\text{KPa} \\ (-2200\ \text{psi}) \end{matrix}$$

$$\tau(\text{limit}) = (2200)\frac{.3125^2}{.3125^2 - .2845^2} = \begin{matrix} 8.861\times10^{4}\,\text{KPa} \\ \underline{(12853\ \text{psi})} \end{matrix}$$

$$\sigma_\ell(\text{proof}) = 10653\times1.5 = \begin{matrix} 1.102\times10^{5}\,\text{KPa} \\ (15980\ \text{psi}) \end{matrix}$$

$$\sigma_H(\text{proof}) = 23505\times1.5 = \begin{matrix} 2.431\times10^{5}\,\text{KPa} \\ (35258\ \text{psi}) \end{matrix}$$

$$\sigma_r(\text{proof}) = -2200\times1.5 = \begin{matrix} -2.275\times10^{4}\,\text{KPa} \\ (-3300\ \text{psi}) \end{matrix}$$

$$\tau(\text{proof}) = 12853\times1.5 = \begin{matrix} 1.329\times10^{5}\,\text{KPa} \\ \underline{\underline{(19280\ \text{psi})}} \end{matrix}$$

$$\sigma_E = .707\sqrt{(15980-35258)^2 + (35258+3300)^2 + (-3300-15980)^2} = \begin{matrix} 2.302\times10^{5}\,\text{KPa} \\ \underline{\underline{(33387\ \text{psi})}} \end{matrix}$$

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Tube Analysis (cont)
Tube Assy 41004829-106 (cont)

$$\left.\begin{array}{l} M.S._{YIELD} = \dfrac{120000(.91)}{33387} - 1 = \boxed{2.27} \\ \\ M.S._{\substack{SHEAR\\YIELD}} = \dfrac{(.55)(120000)(.91)}{19280} - 1 = \boxed{2.12} \end{array}\right\} \text{(proof pressure only)}$$

$$\sigma_{\ell}\,(burst) = 10653 \times 2.5 = \begin{array}{l} 1.836 \times 10^{5}\ KPa \\ (26633\ psi) \end{array}$$

$$\sigma_{H}\,(burst) = 23505 \times 2.5 = \begin{array}{l} 4.051 \times 10^{5}\ KPa \\ (58763\ psi) \end{array}$$

$$\sigma_{r}\,(burst) = -2200 \times 2.5 = \begin{array}{l} -3.792 \times 10^{4}\ KPa \\ (-5500\ psi) \end{array}$$

$$\tau\,(burst) = 12853 \times 2.5 = \begin{array}{l} 2.215 \times 10^{5}\ KPa \\ \underline{\underline{(32133\ psi)}} \end{array}$$

$$\sigma_{E} = .707\sqrt{(26633-58763)^{2} + (58763+5500)^{2} + (-5500-26633)^{2}} = \begin{array}{l} 3.836 \times 10^{5}\ KPa \\ \underline{\underline{(55645\ psi)}} \end{array}$$

$$\left.\begin{array}{l} M.S._{ULT} = \dfrac{142000(.87)}{55645} - 1 = \boxed{1.22} \\ \\ M.S._{\substack{SHEAR\\ULT}} = \dfrac{(.55)(142000)(.87)}{32133} - 1 = \boxed{1.11} \end{array}\right\} \text{(burst pressure only)}$$

41004640 - Landing Gear, Active Control

Analysis - Adapter 41004819-001 (see Fig A-1)

Adapter is at top of MLG Support Assy, bolted to top and cut from square stock as an elbow. Cross section is square outside and circular inside, making it stronger than a simple cylinder. Part will be analyzed as a cylinder using min wall thickness as constant (very conservative). (Roark, 4th Ed., Table XIII, Case 35, P. 308).

*Min Top Wall $= (2.75-.010)-(1.88+.010)-\frac{1}{2}(1.00+.010) = \begin{matrix} .00876\text{M} \\ (.345\text{ in}) \end{matrix}$

*Min Side Wall $= (.70-.010)-\frac{1}{2}(1.00+.010) = \begin{matrix} .00470\text{M} \\ (.185\text{ in}) \end{matrix}$

*Min Threaded Fluid Conn $= (2.75-.010)-(1.88+.010)-(\frac{1.3125}{2} = \begin{matrix} .00492\text{M} \\ (.19375\text{ in}) \end{matrix}$

*See Fig. I

$a = .69-.185 = \begin{matrix} .01283\text{M} \\ (.505\text{ in}) \end{matrix}$ $\quad b = \begin{matrix} .01753\text{M} \\ (.69\text{ in}) \end{matrix}$ $\quad p = \begin{matrix} 1.517\times10^4\text{ KPa} \\ (2200\text{ psi}) \end{matrix}$ (limit)

$$\sigma_\ell = p\frac{a^2}{b^2-a^2} = (2200)\frac{.505^2}{.69^2-.505^2} = \begin{matrix} 1.750\times10^4\text{ KPa} \\ \underline{(2538\text{ psi})} \end{matrix}$$

$$\sigma_H = p\frac{b^2+a^2}{b^2-a^2} = (2200)\frac{.69^2+.505^2}{.69^2-.505^2} = \begin{matrix} 5.016\times10^4\text{ KPa} \\ \underline{(7276\text{ psi})} \end{matrix}$$

$$\sigma_r = \begin{matrix} -1.517\times10^4\text{ KPa} \\ (-2200\text{ psi}) \end{matrix}$$

$$\tau = p\frac{b^2}{b^2-a^2} = (2200)\frac{.69^2}{.69^2-.505^2} = \begin{matrix} 3.266\times10^4\text{ KPa} \\ \underline{(4738\text{ psi})} \end{matrix}$$

$$\sigma_\ell(\text{proof}) = 2538\times1.5 = \begin{matrix} 2.625\times10^4\text{ KPa} \\ (3807\text{ psi}) \end{matrix}$$

$$\sigma_H(\text{proof}) = 7276\times1.5 = \begin{matrix} 7.524\times10^4\text{ KPa} \\ (10914\text{ psi}) \end{matrix}$$

$$\sigma_r(\text{proof}) = -2200\times1.5 = \begin{matrix} -2.275\times10^4\text{ KPa} \\ (-3300\text{ psi}) \end{matrix}$$

$$\tau(\text{proof}) = 4738\times1.5 = \begin{matrix} 4.900\times10^4\text{ KPa} \\ \underline{\underline{(7107\text{ psi})}} \end{matrix}$$

Analysis - Adapter 41004819-001 (cont)

$$\sigma_E = .707\sqrt{(3807-10914)^2+(10914+3300)^2+(-3300-3807)^2} = \underline{\underline{\begin{matrix}8.485\times10^4 \text{ KPa} \\ (12308 \text{ psi})\end{matrix}}}$$

$$M.S._{YIELD} = \frac{145000(.92)}{12308} - 1 = \boxed{9.84}$$

$$M.S._{\substack{SHEAR\\YIELD}} = \frac{(.55)(145000)(.92)}{7107} - 1 = \boxed{9.32}$$

$$\sigma_\ell(\text{burst}) = 2538\text{x}2.5 = \begin{matrix}4.374\times10^4 \text{ KPa} \\ (6345 \text{ psi})\end{matrix}$$

$$\sigma_H(\text{burst}) = 7276\text{x}2.5 = \begin{matrix}1.254\times10^5 \text{ KPa} \\ (18190 \text{ psi})\end{matrix}$$

$$\sigma_r(\text{burst}) = -2200\text{x}2.5 = \begin{matrix}-3.792\times10^4 \text{ KPa} \\ (-5500 \text{ psi})\end{matrix}$$

$$\tau(\text{burst}) = 4738\text{x}2.5 = \underline{\underline{\begin{matrix}8.166\times10^4 \text{ KPa} \\ (11845 \text{ psi})\end{matrix}}}$$

$$\sigma_E = .707\sqrt{(6345-18190)^2+(18190+5500)^2+(-5500-6345)^2} = \underline{\underline{\begin{matrix}1.414\times10^5 \text{ KPa} \\ (20513 \text{ psi})\end{matrix}}}$$

$$M.S._{ULT} = \frac{155000(.92)}{20513} - 1 = \boxed{5.95}$$

$$M.S._{\substack{SHEAR\\ULT}} = \frac{(.55)(155000)(.92)}{11845} - 1 = \boxed{5.62}$$

Loading on hold-down bolts = hydraulic end load + load due to motion of tubes & fittings between adapter & servovalve (which is tied to structure).
Assume entire load of tubes imposes moment on end of adapter, moment arm at C.G. of tubes (very conservative).

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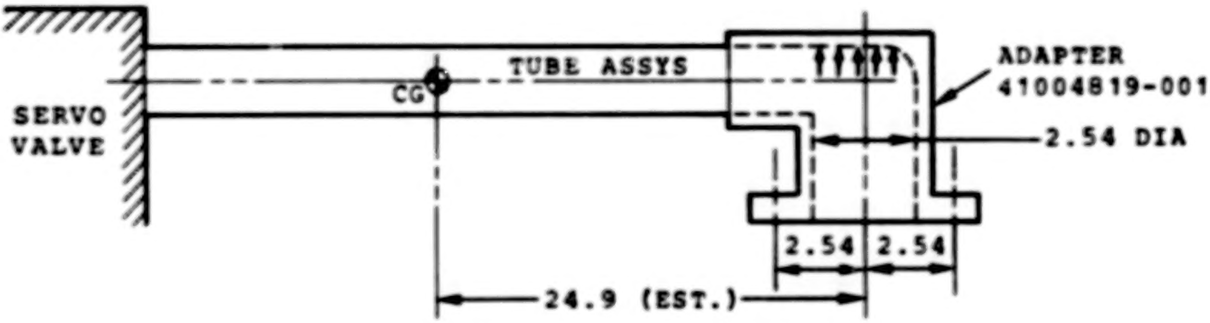
Analysis - Adapter 41004819-001 (cont)



DIMENSIONS IN CM

Vertical Load = $(2200 \text{ psi})(\frac{\pi}{4})(1.00)^2 = \genfrac{}{}{0pt}{}{7686\text{N}}{(1728 \text{ lb})}$

Wt(tube assys) = $2(.81)+(.48)+(.97)+(1.10)+(1.35) = \genfrac{}{}{0pt}{}{24.55\text{N}}{(5.52 \text{ lb})}$

Moment = $(5.52)(9.8) = \genfrac{}{}{0pt}{}{6.112\text{N-M}}{(54.096 \text{ in-lb})}$

Assume moment reacted by 2 hold-down bolts:

Load/bolt = $\frac{1}{4}(1728) + \frac{1}{2}\left[\frac{54.096}{2.00}\right] = \genfrac{}{}{0pt}{}{2162\text{N}}{\underline{\underline{(486.096 \text{ lb})}}}$

Min breaking strength of bolt = $\genfrac{}{}{0pt}{}{1.294\times10^4\text{N}}{(2910 \text{ lb})}$
(NAS1351C4H12)

Assume burst pressure & max 'G' factor = 5.85 on Wt:

Max load/bolt = $\frac{1}{4}(1728\times2.5)+\frac{1}{2}\left[\frac{54.10\times5.85}{2.00}\right] = \genfrac{}{}{0pt}{}{5156\text{N}}{\underline{\underline{(1159.12 \text{ lb})}}}$

$M.S._{\substack{BOLT\\ULT}} = \frac{2910}{1159.12} - 1 = \boxed{1.51}$ (bolt)

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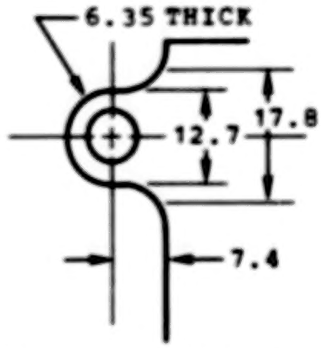
Analysis - Adapter 41004819-001 (cont)

$$\sigma_b \text{(on tab)} = \frac{6M}{bt^2} = \frac{6(1159.12 \text{x} .29)}{(.50)(.25)^2} \text{ (very conservative)}$$

$$\sigma_b = 4.449 \text{x} 10^5 \text{ KPa}$$

$$\underline{\underline{(64540 \text{ psi})(\text{ULT})}}$$

$$M.S._{ULT} = \frac{155000 \text{x} .92}{64540} - 1 = \boxed{1.21} \text{ (lug)}$$



DIMENSIONS IN MM

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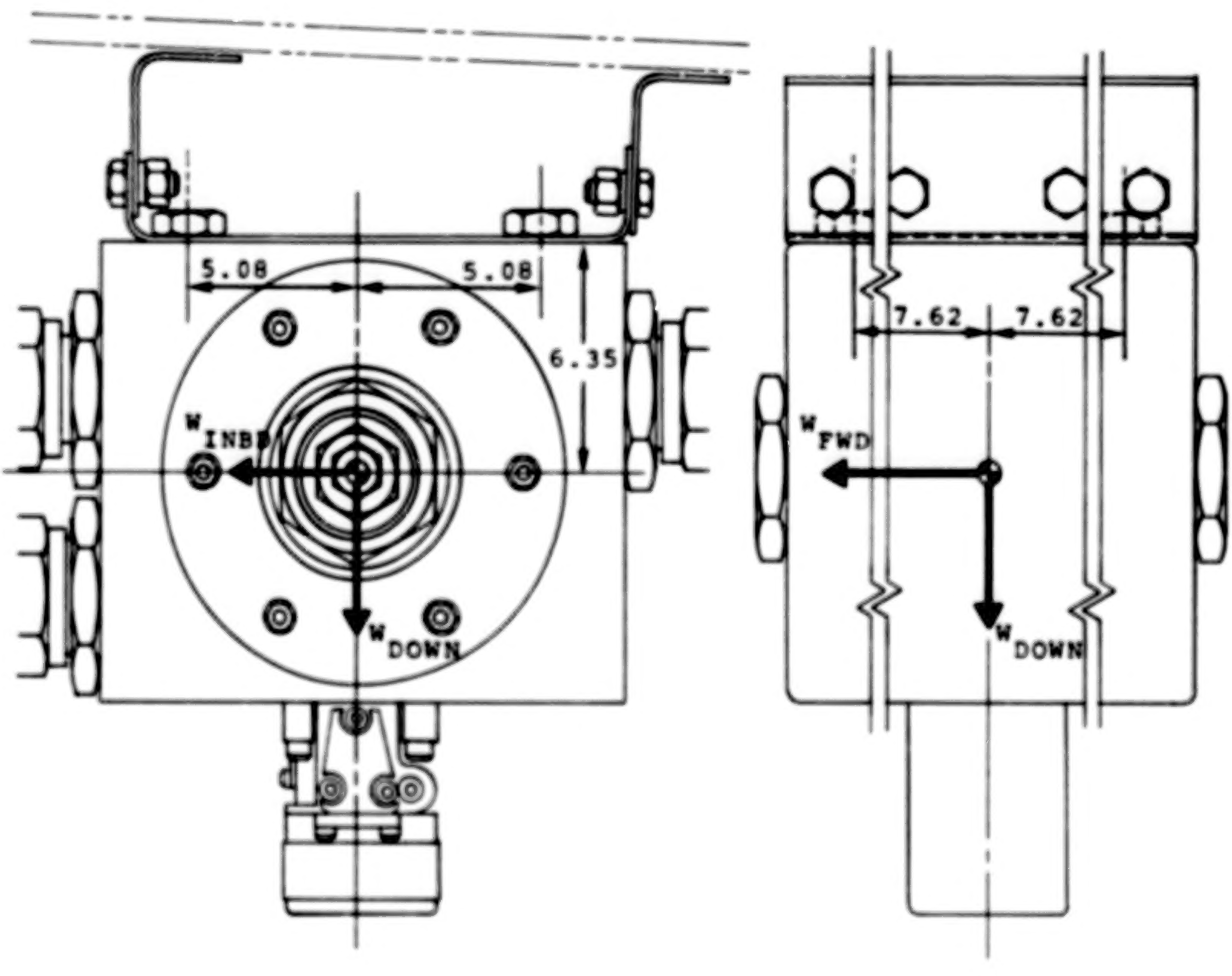
Servo Valve Brackets 41004819-007, -008

Assume weight of all components from 41004819-001 Adapter to 41004819-002 Manifold are reacted at C.G. of 23241830 servo valve by the above brackets (very conservative).

Total Wt=26.5+11.53+2.28=179.3N (40.31 lb)=W



DIMENSIONS IN CM

Figure A-2. Servovalve Brackets

$W_{AFT}=1.5W$ $\qquad$ $W_{OUTBD}=1.5W$

$W_{FWD}=W(G_{FWD})=1.5W$ $\qquad$ $W_{DOWN}=W(G_{DOWN})=5.85W$ $\qquad$ $W_{UP}=W(G_{UP})=2.1W$ $\qquad$ $W_{INBD}=W(G_{INBD})=1.5W$

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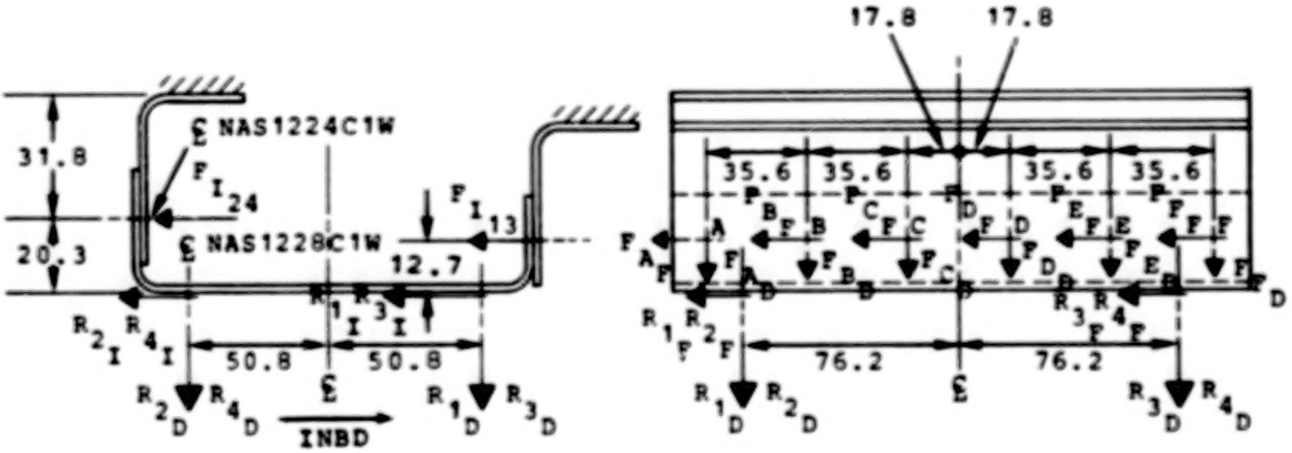
Servo Valve Brackets 41004819-007, -008 (cont)

Servo Valve Bolt Loads



DIMENSIONS IN MM

$$(\Sigma F_D)\ W_{DOWN}=R_{1_D}+R_{2_D}+R_{3_D}+R_{4_D}\longrightarrow R'_{1_D}=R'_{2_D}=R'_{3_D}=R'_{4_D}=.25W_{DOWN} \qquad (1)$$

$$(\Sigma M_I)\ W_{INBD}(2.50)=(R_{2_D}+R_{4_D})(2.00)-(R_{1_D}+R_{3_D})(2.00)$$

$$1.25W_{INBD}=-(R_{2_D}+R_{4_D})+(R_{1_D}+R_{3_D})\longrightarrow \text{let } K_D=-(R_{2_D}+R_{4_D})=(R_{1_D}+R_{3_D})$$

$$2K_D=1.25W_{INBD}$$

$$K_D=.625W_{INBD}\longrightarrow R_{2_D}+R_{4_D}=-.625\ W_{INBD}\ \&\ R_{1_D}+R_{3_D}=+.625\ W_{INBD}$$

from symmetry

$$R''_{1_D}=+.3125W_{INBD} \quad R''_{2_D}=-.3125W_{INBD} \quad R''_{3_D}=+.3125W_{INBD} \quad R''_{4_D}=-.3125W_{INBD} \qquad (2)$$

$$(\Sigma M_F)\ W_{FWD}(2.50)=(R_{3_D}+R_{4_D})(3.00)-(R_{1_D}+R_{2_D})(3.00)$$

$$.83333W_{FWD}=(R_{3_D}+R_{4_D})-(R_{1_D}+R_{2_D})\longrightarrow \text{let } K'_D=R_{3_D}+R_{4_D}=-(R_{1_D}+R_{2_D})$$

$$2K'_D=.83333W_{FWD}$$

$$K'_D=.41667W_{FWD}\longrightarrow R_{3_D}+R_{4_D}=.41667W_{FWD}\ \&\ R_{1_D}+R_{2_D}=-.41667W_{FWD}$$

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Servo Valve Brackets 41004819-007, -008 (cont)

Servo Valve Bolt Loads (cont)

from symmetry

$$R'''_{1_D}=-.20833W_{FWD} \quad R'''_{2_D}=-.20833W_{FWD} \quad R'''_{3_D}=.20833W_{FWD} \quad R'''_{4_D}=.20833W_{FWD} \qquad (3)$$

Combining (1), (2), (3) = (4) $W_{DOWN}=5.85(40.31)=\genfrac{}{}{0pt}{}{1049N}{(235.8135\ lb)}$

$$W_{INBD}=W_{FWD}=1.5(40.31)=\genfrac{}{}{0pt}{}{2[illegible]9.0N}{60.465\ lb)}$$

$$\left.\begin{array}{l}
R_{1_D}=.25W_{DOWN}+.3125W_{INBD}-.20833W_{FWD}=\genfrac{}{}{0pt}{}{290.2N}{(65.25201\ lb)} \\[2ex]
R_{2_D}=.25W_{DOWN}-.3125W_{INBD}-.20833W_{FWD}=\genfrac{}{}{0pt}{}{122.2N}{(27.46139\ lb)} \\[2ex]
R_{3_D}=.25W_{DOWN}+.3125W_{INBD}+.20833W_{FWD}=\genfrac{}{}{0pt}{}{402.3N}{(90.44536\ lb)} \\[2ex]
R_{4_D}=.25W_{DOWN}-.3125W_{INBD}+.20833W_{FWD}=\genfrac{}{}{0pt}{}{234.2N}{(52.65474\ lb)}
\end{array}\right\}(4)$$

$$(\Sigma F_I)\ W_{INBD}=R_{1_I}+R_{2_I}+R_{3_I}+R_{4_I} \longrightarrow R_{1_I}=R_{2_I}=R_{3_I}=R_{4_I}=.25W_{INBD}=\genfrac{}{}{0pt}{}{67.24N}{(15.1163\ lb)} \qquad (5)$$

$$(\Sigma F_F)\ W_{FWD}=R_{1_F}+R_{2_F}+R_{3_F}+R_{4_F} \longrightarrow R_{1_F}=R_{2_F}=R_{3_F}=R_{4_F}=.25W_{FWD}=\genfrac{}{}{0pt}{}{67.24N}{(15.1163\ lb)} \qquad (6)$$

<u>Analysis of NAS1228C1W bolt (1/2-20 bolt)</u>

Max tension load $=\overset{(4)}{R_{3_D}}=.25W_{DOWN}+.3125W_{INBD}+.20833W_{FWD}$

$$R_{3_D}=\genfrac{}{}{0pt}{}{402.3N}{(90.44536\ lb)}$$

$$\sigma_t=\frac{90.44536}{.1599}=\genfrac{}{}{0pt}{}{3900KPa}{\underline{\underline{(565.637\ psi)}}}$$

$$M.S._{YIELD}=\frac{118000(.91)}{565.637}-1=\boxed{LARGE}$$

Max shear load $=\sqrt{\overset{(5)}{R^2_{3_I}}+\overset{(6)}{R^2_{3_F}}}=\sqrt{(.25W_{INBD})^2+(.25W_{FWD})^2}=\genfrac{}{}{0pt}{}{95.09N}{(21.37768\ lb)}$

41004640 - Landing Gear, Active Control

Servo Valve Brackets 41004819-007, -008 (cont)
Servo Valve Bolt Loads (cont)

$$\tau = \frac{21.37768}{.1486} = 991.8\text{KPa} \; \underline{\underline{(143.861 \text{ psi})}}$$

$$M.S._{YIELD} = \frac{.55*[118000(.91)]}{143.861} - 1 = \boxed{\text{LARGE}}$$

Bracket Bolt Loads

$$(\Sigma M_{D_{1-3}})\; R_{1_D}(3.00) - R_{3_D}(3.00) = 3.50(\overbrace{F_{A_D} + F_{F_D}}^{2F_{A_D}}) + 2.10(\overbrace{F_{B_D} + F_{E_D}}^{2F_{B_D}}) + .70(\overbrace{F_{C_D} + F_{D_D}}^{2F_{C_D}})$$

$$3.00(R_{1_D} - R_{3_D}) = 7F_{A_{D_{13}}} + 4.2F_{B_{D_{13}}} + 1.4F_{C_{D_{13}}}$$

$$(\Sigma M_{D_{2-4}})\; 3.00(R_{2_D} - R_{4_D}) = 7F_{A_{D_{24}}} + 4.2F_{B_{D_{24}}} + 1.5F_{C_{D_{24}}}$$

$$F_{A_D} = \frac{M r_{A_D}}{I} \text{(BRUHN, P.D1.14) where } M_{1-3} = 3.00(R_{1_D} - R_{3_D})$$

$$M_{2-4} = 3.00(R_{2_D} - R_{4_D})$$

$$I = 2[r_{A_D}^2 + r_{B_D}^2 + r_{C_D}^2] = 2[3.50^2 + 2.10^2 + .70^2]$$

$$= 34.30$$

*Ref. MIL-HDBK-5C, Para. 1.4.6.3

Servo Valve Brackets 41004819-007, -008 (cont)
Bracket Bolt Loads (cont)

$$\left.\begin{aligned}
&F'_{A_{D_{13}}}=F'_{F_{D_{13}}}=\frac{(M_{1-3}\text{ or }M_{2-4})(3.50)}{34.30}=.30612\ (R_{1_D}-R_{3_D});F'_{A_{D_{24}}}=F'_{F_{D_{24}}}\\
&\qquad=.30612(R_{2_D}-R_{4_D})\\
&F'_{B_{D_{13}}}=F'_{E_{D_{13}}}=\frac{(M_{1-3}\text{ or }M_{2-4})(2.10)}{34.30}=.18367\ (R_{1_D}-R_{3_D});F'_{B_{D_{24}}}=F'_{E_{D_{24}}}\\
&\qquad=.18367(R_{2_D}-R_{4_D})\\
&F'_{C_{D_{13}}}=F'_{D_{D_{13}}}=\frac{(M_{1-3}\text{ or }M_{2-4})(.70)}{34.30}=.06122\ (R_{1_D}-R_{3_D});F'_{C_{D_{24}}}=F'_{D_{D_{24}}}\\
&\qquad=.06122(R_{2_D}-R_{4_D})
\end{aligned}\right\}(7)$$

$$\left.\begin{aligned}
&(\Sigma F_{D_{1-3}})R_{1_D}+R_{3_D}=2F_{A_D}+2F_{B_D}+2F_{C_D}\longrightarrow F''_{A_{D_{13}}}=F''_{B_{D_{13}}}=F''_{C_{D_{13}}}=F''_{D_{D_{13}}}=F''_{E_{D_{13}}}=F''_{F_{D_{13}}}\\
&\qquad=\frac{1}{6}(R_{1_D}+R_{3_D})\\
&(\Sigma F_{D_{2-4}})R_{2_D}+R_{4_D}=2F_{A_D}+2F_{B_D}+2F_{C_D}\longrightarrow F''_{A_{D_{24}}}=F''_{B_{D_{24}}}=F''_{C_{D_{24}}}=F''_{D_{D_{24}}}=F''_{E_{D_{24}}}=F''_{F_{D_{24}}}\\
&\qquad=\frac{1}{6}(R_{2_D}+R_{4_D})
\end{aligned}\right\}(8)$$

$$(\Sigma M_{F_{1-3}})(R_{1_F}+R_{3_F})(.50)=3.50(-F_{A_{D_{13}}}+F_{F_{D_{13}}})+2.10(-F_{B_{D_{13}}}+F_{E_{D_{13}}})$$
$$+.70(-F_{C_{D_{13}}}+F_{D_{D_{13}}})$$

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Servo Valve Brackets 41004819-007, -008 (cont)
Bracket Bolt Loads (cont)

$$(\Sigma M_{F_{2-4}})(R_{2_F}+R_{4_F})(.80)=3.50(-F_{A_{D_{24}}}+F_{F_{D_{24}}})+2.10(-F_{B_{D_{24}}}+F_{E_{D_{24}}})$$
$$+.70(-F_{C_{D_{24}}}+F_{D_{D_{24}}})$$

$$\left.\begin{aligned}
-F'''_{A_{D_{13}}} &= F'''_{F_{D_{13}}} = \frac{(.50)(R_{1_F}+R_{3_F})(3.50)}{34.30} = .05102\ (R_{1_F}+R_{3_F})\\
-F'''_{B_{D_{13}}} &= F'''_{E_{D_{13}}} = \frac{(.50)(R_{1_F}+R_{3_F})(2.10)}{34.30} = .03061\ (R_{1_F}+R_{3_F})\\
-F'''_{C_{D_{13}}} &= F'''_{D_{D_{13}}} = \frac{(.50)(R_{1_F}+R_{3_F})(.70)}{34.30} = .01020\ (R_{1_F}+R_{3_F})\\
-F'''_{A_{D_{24}}} &= F'''_{F_{D_{24}}} = \frac{(.80)(R_{2_F}+R_{4_F})(3.50)}{34.30} = .08163\ (R_{2_F}+R_{4_F})\\
-F'''_{B_{D_{24}}} &= F'''_{E_{D_{24}}} = \frac{(.80)(R_{2_F}+R_{4_F})(2.10)}{34.30} = .04898\ (R_{2_F}+R_{4_F})\\
-F'''_{C_{D_{24}}} &= F'''_{D_{D_{24}}} = \frac{(.80)(R_{2_F}+R_{4_F})(.70)}{34.30} = .01633\ (R_{2_F}+R_{4_F})
\end{aligned}\right\}(9)$$

1-3

Combining (7), (8), (9) = (10) (for right side)

$$\left.\begin{aligned}
F_{A_{D_{13}}} &= F'_{A_{D_{13}}}+F''_{A_{D_{13}}}+F'''_{A_{D_{13}}} = .47279R_{1_D}-.13945R_{3_D}-.05102(R_{1_F}+R_{3_F})\\
F_{A_{D_{13}}} &= \begin{matrix}74.26\text{N}\\(16.69543\text{ lb})\end{matrix}
\end{aligned}\right\}(10)$$

41004640 - Landing Gear, Active Control

Servo Valve Brackets 41004819-007, -008 (cont)

Bracket Bolt Loads (cont)

$$
\left.\begin{array}{l}
F_{B_{D_{13}}}=F'_{B_{D_{13}}}+F''_{B_{D_{13}}}+F'''_{B_{D_{13}}}=.35034R_{1_D}-.017R_{3_D}-.03061(R_{1_F}+R_{3_F}) \\[2ex]
F_{B_{D_{13}}}=\begin{array}{l}90.73N \\ (20.39740\ lb)\end{array} \\[2ex]
F_{C_{D_{13}}}=F'_{C_{D_{13}}}+F''_{C_{D_{13}}}+F'''_{C_{D_{13}}}=.22789R_{1_D}-.10545R_{3_D}-.01020(R_{1_F}+R_{3_F}) \\[2ex]
F_{C_{D_{13}}}=\begin{array}{l}107.2N \\ (24.09937\ lb)\end{array} \\[2ex]
F_{D_{D_{13}}}=F'_{D_{D_{13}}}+F''_{D_{D_{13}}}+F'''_{D_{D_{13}}}=.22789R_{1_D}+.10545R_{3_D}+.01020(R_{1_F}+R_{3_F}) \\[2ex]
F_{D_{D_{13}}}=\begin{array}{l}109.9N \\ (24.71612\ lb)\end{array} \\[2ex]
F_{E_{D_{13}}}=F'_{E_{D_{13}}}+F''_{E_{D_{13}}}+F'''_{E_{D_{13}}}=.35034R_{1_D}-.017R_{3_D}+.03061(R_{1_F}+R_{3_F}) \\[2ex]
F_{E_{D_{13}}}=\begin{array}{l}98.96N \\ (22.24824\ lb)\end{array} \\[2ex]
F_{F_{D_{13}}}=F'_{F_{D_{13}}}+F''_{F_{D_{13}}}+F'''_{F_{D_{13}}}=.47279R_{1_D}-.13945R_{3_D}+.05102(R_{1_F}+R_{3_F}) \\[2ex]
F_{F_{D_{13}}}=\begin{array}{l}87.98N \\ (19.78036\ lb)\end{array}
\end{array}\right\} \quad (10)
$$

41004640 - Landing Gear, Active Control

Servo Valve Brackets 41004819-007, -008 (cont)

Bracket Bolt Loads (cont)

2-4

Combining (7), (8), (9) = (10) (for left side)

$$\left.\begin{aligned}
&F_{A_{D_{24}}}=F'_{A_{D_{24}}}+F''_{A_{D_{24}}}+F'''_{A_{D_{24}}}=.47279R_{2_D}-.13945R_{4_D}-.08163(R_{2_F}+R_{4_F})\\
&F_{A_{D_{24}}}=\begin{matrix}14.11N\\(3.17288\text{ lb})\end{matrix}\\
&F_{B_{D_{24}}}=F'_{B_{D_{24}}}+F''_{B_{D_{24}}}+F'''_{B_{D_{24}}}=.35034R_{2_D}-.017R_{4_D}-.04898(R_{2_F}+R_{4_F})\\
&F_{B_{D_{24}}}=\begin{matrix}32.23N\\(7.24490\text{ lb})\end{matrix}\\
&F_{C_{D_{24}}}=F'_{C_{D_{24}}}+F''_{C_{D_{24}}}+F'''_{C_{D_{24}}}=.22789R_{2_D}+.10545R_{4_D}-.01633(R_{2_F}+R_{4_F})\\
&F_{C_{D_{24}}}=\begin{matrix}50.34N\\(11.31692\text{ lb})\end{matrix}\\
&F_{D_{D_{24}}}=F'_{D_{D_{24}}}+F''_{D_{D_{24}}}+F'''_{D_{D_{24}}}=.22789R_{2_D}+.10545R_{4_D}+.01633(R_{2_F}+R_{4_F})\\
&F_{D_{D_{24}}}=\begin{matrix}54.73N\\(12.30432\text{ lb})\end{matrix}\\
&F_{E_{D_{24}}}=F'_{E_{D_{24}}}+F''_{E_{D_{24}}}+F'''_{E_{D_{24}}}=.35034R_{2_D}-.017R_{4_D}+.04898(R_{2_F}+R_{4_F})\\
&F_{E_{D_{24}}}=\begin{matrix}45.40N\\(10.20649\text{ lb})\end{matrix}\\
&F_{F_{D_{24}}}=F'_{F_{D_{24}}}+F''_{F_{D_{24}}}+F'''_{F_{D_{24}}}=.47279R_{2_D}-.13945R_{4_D}+.08163(R_{2_F}+R_{4_F})\\
&F_{F_{D_{24}}}=\begin{matrix}36.07N\\(8.10865\text{ lb})\end{matrix}
\end{aligned}\right\}(10)$$

41004640 - Landing Gear, Active Control

Servo Valve Brackets 41004819-007, -008 (cont)
Bracket Bolt Loads (cont)

$$\left.\begin{aligned}
&(\Sigma F_{F_{1-3}})R_{1_F}+R_{3_F}=F_{A_{F_{13}}}+F_{B_{F_{13}}}+F_{C_{F_{13}}}+F_{D_{F_{13}}}+F_{E_{F_{13}}}+F_{F_{F_{13}}}\longrightarrow F_{A_{F_{13}}}=F_{B_{F_{13}}}\\
&\qquad =F_{C_{F_{13}}}=F_{D_{F_{13}}}=F_{E_{F_{13}}}=F_{F_{F_{13}}}=\frac{1}{6}(R_{1_F}+R_{3_F})\\
&(\Sigma F_{F_{2-4}})R_{2_F}+R_{4_F}=F_{A_{F_{24}}}+F_{B_{F_{24}}}+F_{C_{F_{24}}}+F_{D_{F_{24}}}+F_{E_{F_{24}}}+F_{F_{F_{24}}}\longrightarrow F_{A_{F_{24}}}=F_{B_{F_{24}}}\\
&\qquad =F_{C_{F_{24}}}=F_{D_{F_{24}}}=F_{E_{F_{24}}}=F_{F_{F_{24}}}=\frac{1}{6}(R_{2_F}+R_{4_F})\\
&\qquad \frac{1}{6}(R_{1_F}+R_{3_F})=\frac{1}{6}(R_{2_F}+R_{4_F})=\underline{\begin{matrix}22.41N\\(5.0388\ \text{lb})\end{matrix}}
\end{aligned}\right\}(11)$$

$$\left.\begin{aligned}
&(\Sigma F_{I_{1-3}})F_{A_{I_{13}}}=F_{B_{I_{13}}}=F_{C_{I_{13}}}=F_{D_{I_{13}}}=F_{E_{I_{13}}}=F_{F_{I_{13}}}=\frac{1}{6}(R_{1_I}+R_{3_I})\ \text{[tens. or comp.]}\\
&(\Sigma F_{I_{2-4}})F_{A_{I_{24}}}=F_{B_{I_{24}}}=F_{C_{I_{24}}}=F_{D_{I_{24}}}=F_{E_{I_{24}}}=F_{F_{I_{24}}}=\frac{1}{6}(R_{2_I}+R_{4_I})\ \text{[tens. or comp.]}
\end{aligned}\right\}(12)$$

$$\frac{1}{6}(R_{1_I}+R_{3_I})=\frac{1}{6}(R_{2_I}+R_{4_I})=\underline{\begin{matrix}22.41N\\(5.0388\ \text{lb})\end{matrix}}$$

Analysis of NAS1224C1W Bolt (1/4-28 bolt)

$$\text{Max Tension Load} = F_{D_{I_{13}}} = \begin{matrix}22.369N\\(5.0388\ \text{lb})\end{matrix}$$

$$\sigma_t = \frac{5.0388}{.0364} = \begin{matrix}9.544\times10^5\,\text{KPa}\\(138.429\ \text{psi})\end{matrix}$$

$$M.S._{YIELD}=\frac{118000(.91)}{138.429}-1=\boxed{\text{LARGE}}$$

$$\text{Max Shear Load} =\sqrt{F^2_{D_{D_{13}}}+F^2_{D_{I_{13}}}}=\sqrt{(24.71612)^2+(5.0388)^2}=\begin{matrix}112.2N\\(25.2245\ \text{lb})\end{matrix}$$

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Servo Valve Brackets 41004819-007, -008 (cont)
Analysis of NAS1224C1W Bolt (1/4-28 bolt)

$$\tau = \frac{25.2245}{.0326} = \underline{\underline{\begin{matrix}533.4\text{KPa} \\ (773.758 \text{ psi})\end{matrix}}}$$

$$M.S._{YIELD} = \frac{.55[118000(.91)]}{773.75} - 1 = \boxed{\text{LARGE}}$$

At bend of bracket, stress results from tension load and side load tending to bend bracket. The bending is distributed somewhat evenly along the length of the bracket, but the tension load is much less evenly distributed. Conservative analysis will be used.

$$\sigma_b \text{(bending stress)} = \frac{6M}{bt^2} = \frac{6(R_{2_I} + R_{4_I})(1.25+.80)}{(8.00)(.063)^2} = \begin{matrix}8.074\text{X}10^4 \text{KPa} \\ (11711.4 \text{ psi})\end{matrix}$$

$$\sigma_t \text{(tensile stress)} = \frac{F_{D_{D_{13}}}}{\frac{1}{6}bt} = \frac{6(24.71612)}{(8.00)(.063)} = \begin{matrix}2029\text{KPa} \\ (294.24 \text{ psi})\end{matrix}$$

$$\sigma_{TOTAL} \; \sigma_b + \sigma_t = \underline{\underline{\begin{matrix}8.277\text{x}10^4 \text{KPa} \\ (12006 \text{ psi})\end{matrix}}}$$

$$M.S._{YIELD} = \frac{(35000)(.88)}{12006} - 1 = \boxed{1.57}$$

$$\tau = \frac{F_{A_F} + F_{B_F} + F_{C_F} + F_{D_F} + F_{E_F} + F_{F_F}}{bt} = \frac{R_{2_F} + R_{4_F}}{bt} = \frac{30.2326}{(8.00)(.063)} = \underline{\underline{\begin{matrix}413.5\text{KPa} \\ (59.985 \text{ psi})\end{matrix}}}$$

$$M.S._{YIELD} = \frac{.83(27000)(.88)}{59.985} - 1 = \boxed{\text{LARGE}}$$

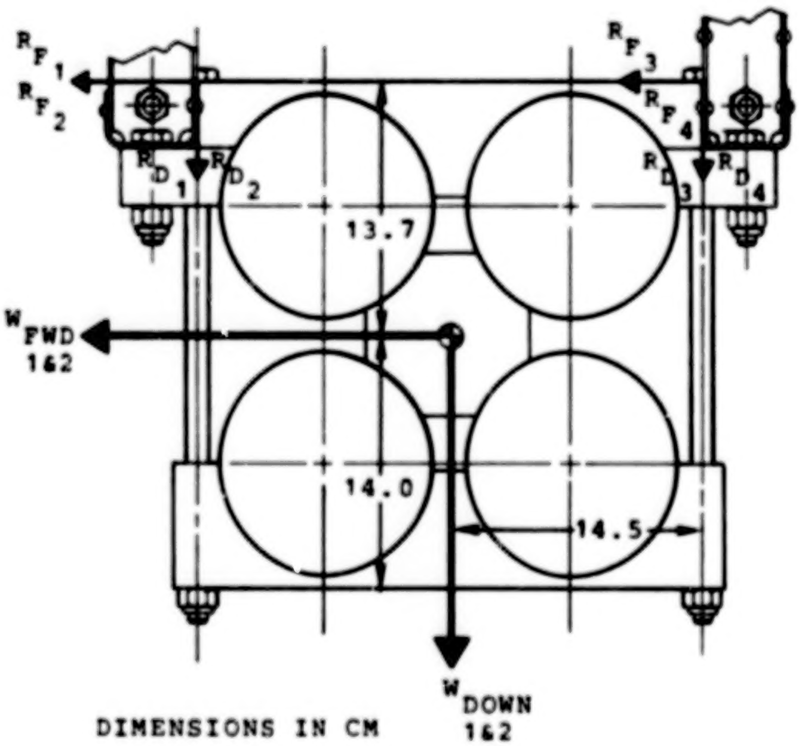
Up load on brackets is much smaller than down load. Since the buckling length of the bracket sheet metal is so small, it will not be necessary to analyze it for "up" load.

41004640 - Landing Gear, Active Control

Accumulator, Clamps & Brackets

Composite Weight (assume reacted at C.G. of assy)

	N	LBS
4 Accumulators (empty) (MS28797-7)	444.8	100.00
2 Clamps (41004819-003)	14.59	3.28
2 Clamps (41004819-004)	31.31	7.04
2 Clamps (41004819-005)	8.095	1.82
4 Brackets (41004819-006)	6.405	1.44
4 Bolts (NAS1228C132)	9.385	2.11
16 Bolts (NAS1226C6)	2.980	.67
2 Bolts (NAS1224C32)	.311	.07
4 Nuts (AN315C4R)	.133	.03
2 Bolts (NAS1223C1)	.0445	.01
1 Valve, Sol. Oper. Shutoff (25200 or 25450)	22.24	5.00
1 Bracket (41004819-009)	.311	.07
Oil for Accumulators (1600 in^3 x.0298 lb/in^3)	212.1	47.68
Accumulator Subtotal	752.7	169.22
1 Manifold (41004819-002)	34.43	7.74
4 Pipe Assy (41004829-105)	9.074	2.04
4 Plug (AN814-12)	3.914	.88
1 Plug (AN814-16)	1.423	.32
4 Union (AN815-12)	5.693	1.28
Total	807.2	181.48



DIMENSIONS IN CM

END VIEW

$W_1 = \frac{1}{2}(169.22)$

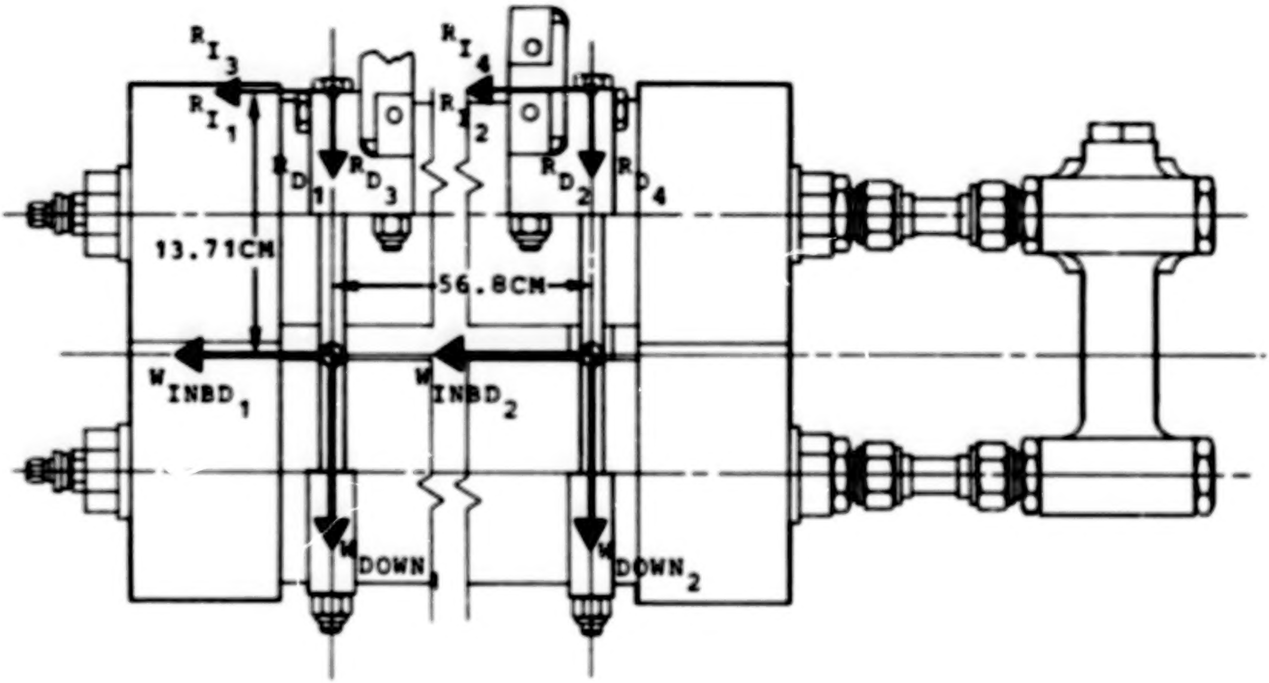
$= 376.4N$ (84.61 lb)

$W_2 = \frac{1}{2}(169.22)$

$+(181.48-169.22)$

$= 430.9N$ (96.87 lb)

41004640 - Landing Gear, Active Controls Accumulator, Clamps & Brackets (cont)



SIDE VIEW

$W_{FWD_1} = 1.5W_1$ $W_{DOWN_1} = 5.85W_1$ $W_{UP_1} = 2.1W_1$ $W_{INBD_1} = 1.5W_1$

$W_{FWD_2} = 1.5W_2$ $W_{DOWN_2} = 5.85W_2$ $W_{UP_2} = 2.1W_2$ $W_{INBD_1} = 1.5W_2$

$W_1 = .87344W_2$

$W_{FWD_1} = \frac{564.5N}{(126.915\ lb)}$ $W_{DOWN_1} = \frac{2202N}{(494.969\ lb)}$ $W_{UP_1} = \frac{790.3N}{(177.681\ lb)}$

$W_{FWD_2} = \frac{646.3N}{(145.305\ lb)}$ $W_{DOWN_2} = \frac{2521N}{(566.690\ lb)}$ $W_{UP_2} = \frac{904.8N}{(203.427\ lb)}$

$W_{INBD_1} = \frac{564.5N}{(126.915\ lb)}$

$W_{INBD_2} = \frac{646.3N}{(145.305\ lb)}$

41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)
Load Calculations

Due to flexure of accumulators and reasonable looseness of clamped assembly, the loadings at area 1 and area 2 can be treated separately.

$$\left.\begin{aligned}(\Sigma F_D)\quad & R'_{D_2}=R'_{D_4}=\tfrac{1}{2}W_{DOWN_2}\\ & R'_{D_1}=R'_{D_3}=\tfrac{1}{2}W_{DOWN_1}\end{aligned}\right\}(1)$$

$$(\Sigma M_I)\quad (W_{INBD_1}+W_{INBD_2})(5.40)=\left[(R''_{D_2}+R''_{D_4})-(R''_{D_1}+R''_{D_3})\right]\left(\frac{22.275}{2}\right)$$

$$-R''_{D_1}=R''_{D_2}=-R''_{D_3}=R''_{D_4}=.12067(W_{INBD_1}+W_{INBD_2})\qquad(2)$$

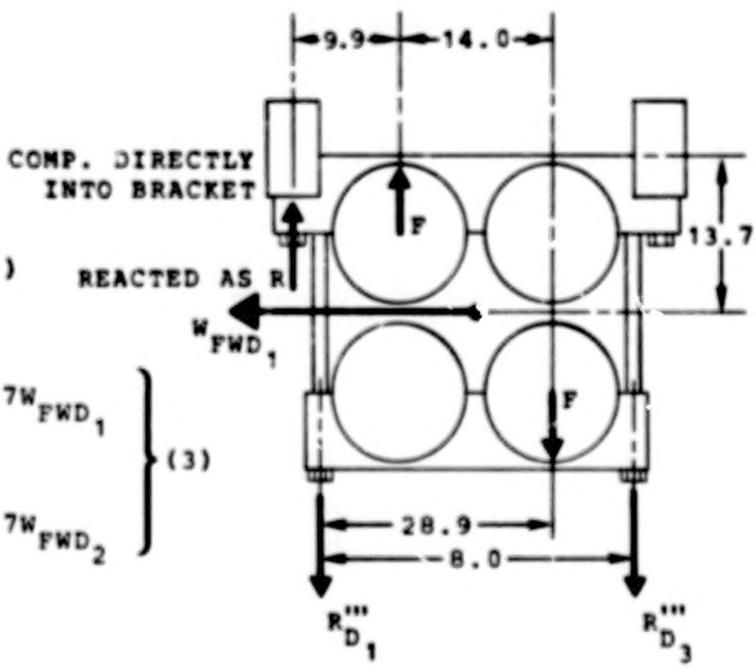
(ΣM_F) Since this is a clamped assembly, loading must be treated as reacting on individual parts instead of as an assembly.

$$M_{F_1}=W_{FWD_1}(5.40)$$

$$F=\left(\frac{5.40}{5.50}\right)W_{FWD_1}$$

$$F=.98182W_{FWD_1}$$

$$R'''_{D_1}=\left(\frac{11.38-8.44}{11.38}\right)(.98182W_{FWD_1})$$



$$\left.\begin{aligned}& R'''_{D_1}=.25365W_{FWD_1} && R'''_{D_3}=.72817W_{FWD_1}\\ \therefore\ & R'''_{D_2}=.25365W_{FWD_2} && R'''_{D_4}=.72817W_{FWD_2}\end{aligned}\right\}(3)$$

DIMENSIONS IN CM

41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)
Load Calculations

Combining (1), (2), (3) = (4)

$$\left.\begin{aligned}
R_{D_1} &= R'_{D_1}+R''_{D_1}+R'''_{D_1}=.5W_{DOWN_1}-.12067\left[W_{INBD_1}+W_{INBD_2}\right]+.25365W_{FWD_1} \\
&= \begin{matrix}1098N\\(246.82770\ lb)\end{matrix} \\
R_{D_2} &= R'_{D_2}+R''_{D_2}+R'''_{D_2}=.5W_{DOWN_2}+.12067\left[W_{INBD_1}+W_{INBD_2}\right]+.25365W_{FWD_2} \\
&= \begin{matrix}1570N\\(353.05040\ lb)\end{matrix} \\
R_{D_3} &= R'_{D_3}+R''_{D_3}+R'''_{D_3}=.5W_{DOWN_1}-.12067\left[W_{INBD_1}+W_{INBD_2}\right]+.72817W_{FWD_1} \\
&= \begin{matrix}1366N\\(307.05141\ lb)\end{matrix} \\
R_{D_4} &= R'_{D_4}+R''_{D_4}+R'''_{D_4}=.5W_{DOWN_2}+.12067\left[W_{INBD_1}+W_{INBD_2}\right]+.72817W_{FWD_2} \\
&= \begin{matrix}1877N\\(422.00053\ lb)\end{matrix}
\end{aligned}\right\}\ (4)$$

$$(\Sigma F_I)\ W_{INBD_1}+W_{INBD_2}=R_{I_1}+R_{I_2}+R_{I_3}+R_{I_4}$$

$$R_{I_1}=R_{I_2}=R_{I_3}=R_{I_4}=.25(W_{INBD_1}+W_{INBD_2})=\begin{matrix}302.7N\\(68.055\ lb)\end{matrix} \qquad (5)$$

$$(\Sigma F_F)\ W_{FWD_1}+W_{FWD_2}=R_{F_1}+R_{F_2}+R_{F_3}+R_{F_4}$$

$$R_{F_1}=R_{F_2}=R_{F_3}=R_{F_4}=.25(W_{FWD_1}+W_{FWD_2})=\begin{matrix}302.7N\\(68.055\ lb)\end{matrix} \qquad (6)$$

Analysis of NAS1228C132 Bolt (1/2-20)

Max Tension Load = $R_{D_4}=.5W_{DOWN_2}+.12067\left[W_{INBD_1}+W_{INBD_2}\right]+.72817W_{FWD_2}$

$$R_{D_4}=\begin{matrix}1877N\\(422.001\ lb)\end{matrix}$$

41004640 - Landing Gear, Active Controls

Load Calculations (cont)
Analysis of NAS1228C132 Bolt (1/2-20)

$$\sigma_t = \frac{422.001}{.1599} = 1.819\times10^{4}\,\text{KPa} \quad \underline{\underline{(2639\ \text{psi})}}$$

$$\text{M.S.}_{\text{YIELD}} = \frac{118000(.91)}{2639} - 1 = \boxed{\text{LARGE}}$$

$$\delta\,(\text{max defl}) = \frac{P\ell}{AE}\ \frac{(422.001)(10.90)}{(.1486)(29\times10^{6})} = .00271\text{MM} \quad (.00106739\ \text{in})$$

$$\text{Max Shear Load} = \sqrt{\overset{(5)}{R_{I_4}^{2}} + \overset{(6)}{R_{F_4}^{2}}} = \sqrt{(68.055)^2 + (68.055)^2} = 428.1\text{N} \quad (96.2443\ \text{lb})$$

$$\tau = \frac{96.2443}{.1486} = 4465\text{KPa} \quad \underline{\underline{(647.674\ \text{psi})}}$$

$$\text{M.S.}_{\text{YIELD}} = \frac{.55[118000(.91)]}{647.674} - 1 = \boxed{\text{LARGE}}$$

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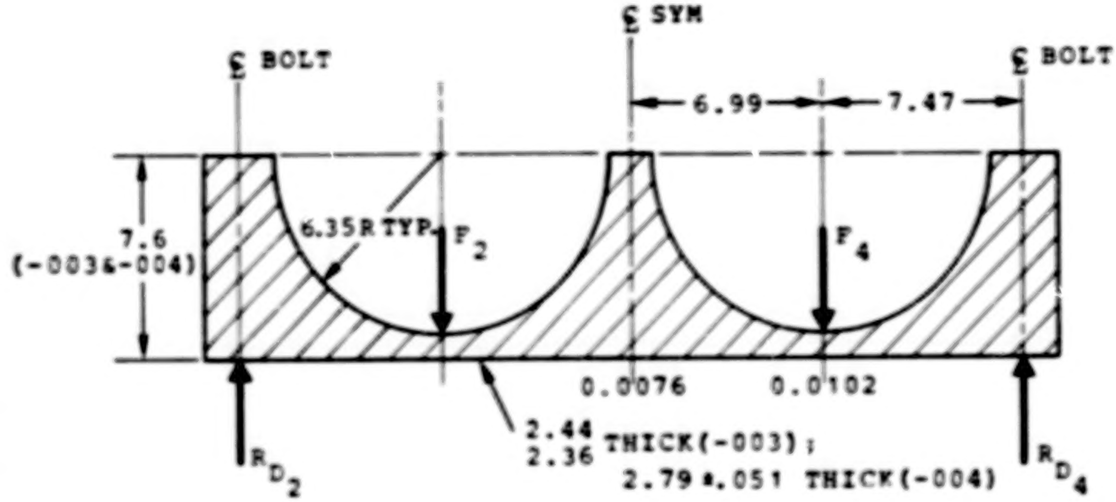
Accumulator, Clamps & Brackets (cont)
Analysis of Lower Clamp (41004819-003)

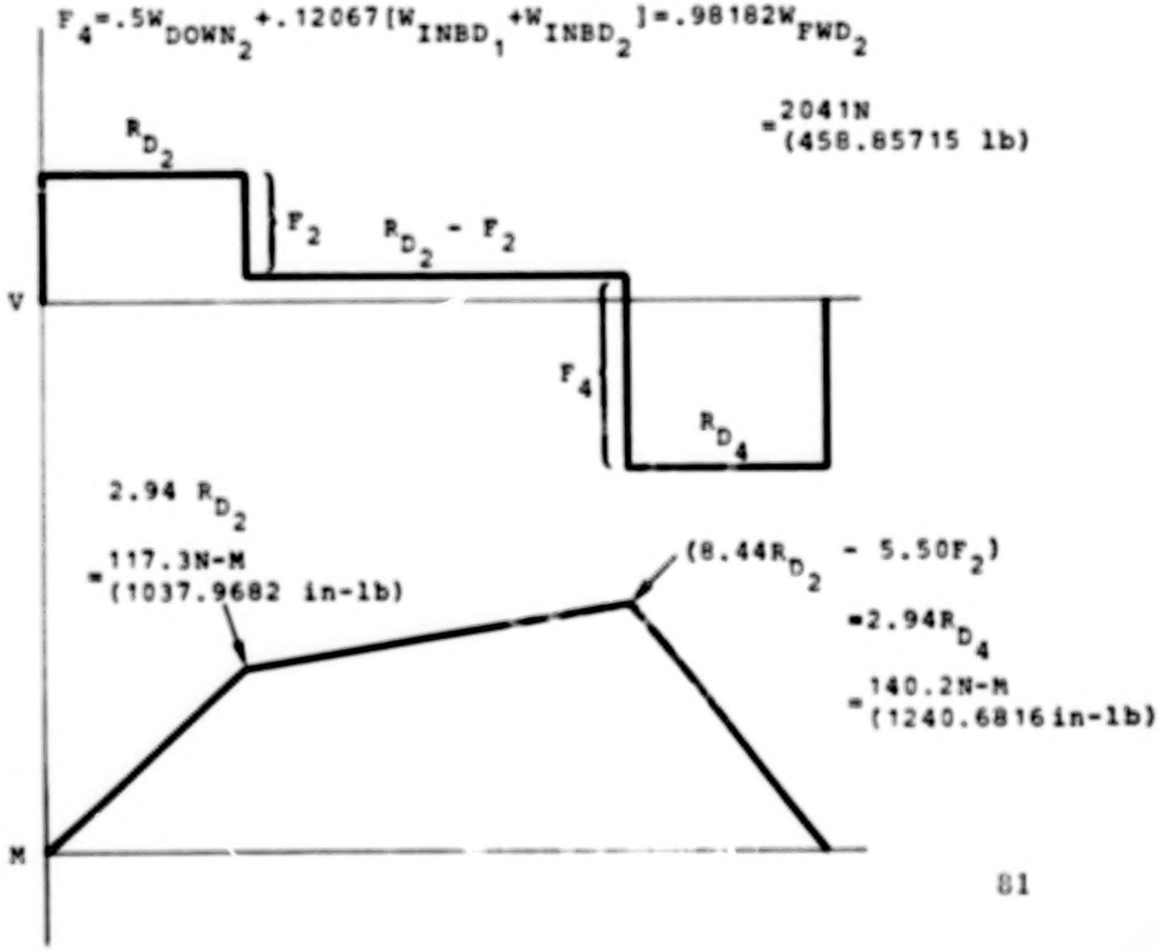


DIMENSIONS IN CM

$$F_2 = .5W_{DOWN_2} + .12067[W_{INBD_1} + W_{INBD_2}] = \begin{matrix}1406N\\(316.19379\ lb)\end{matrix}$$

$$F_4 = .5W_{DOWN_2} + .12067[W_{INBD_1} + W_{INBD_2}] = .98182W_{FWD_2}$$

$$= \begin{matrix}2041N\\(458.85715\ lb)\end{matrix}$$



41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)
Analysis of Lower Clamp (41004819-003) (cont)

$M_{MAX}=2.94R_{D_4}=\begin{matrix}140.2N\text{-}M\\(1240.6816\ in\text{-}lb)\end{matrix}$

$b_{MIN} = \begin{matrix}2.36CM\\(.93\ in)\end{matrix}$

$t_{MIN}=(2.99-2.51)=\begin{matrix}1.22CM\\(.48\ in)\end{matrix}$

$$\sigma_b = \frac{6M}{bt^2} = \frac{6(1240.6816)}{(.93)(.48)^2}$$

$\sigma_b = \begin{matrix}2.395x10^5 KPa\\ \underline{\underline{(34741\ psi)}}\end{matrix}$

$$M.S._{YIELD} = \frac{57000(.85)}{34741} - 1 = \boxed{0.39}$$

$$\tau = \frac{F_4}{bt} = \frac{458.85715}{(.93)(.48)} = \begin{matrix}7087KPa\\ \underline{\underline{(1028\ psi)}}\end{matrix}$$

$$M.S._{YIELD} = \frac{[38000(.91)](\frac{57}{67})}{1028} - 1 = \boxed{LARGE}$$

Analysis of Upper Clamp (41004819-004)

Assume same loading conditions at -003 apply to -004.

$M_{MAX}=2.94R_{D_4}=\begin{matrix}140.2N\text{-}M\\(1240.6816\ in\text{-}lb)\end{matrix}$

$b_{MIN}=\begin{matrix}2.74CM\\(1.08\ in)\end{matrix}$ $\quad t_{MIN}=(2.99-2.51)=\begin{matrix}1.22CM\\(.48\ in)\end{matrix}$

$$\sigma_b = \frac{6M}{bt^2} = \frac{6(1240.6816)}{(1.08)(.48)^2} = \begin{matrix}2.062x10^5 KPa\\ \underline{\underline{(29916\ psi)}}\end{matrix}$$

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Accumulator, Clamps & Brackets (cont)

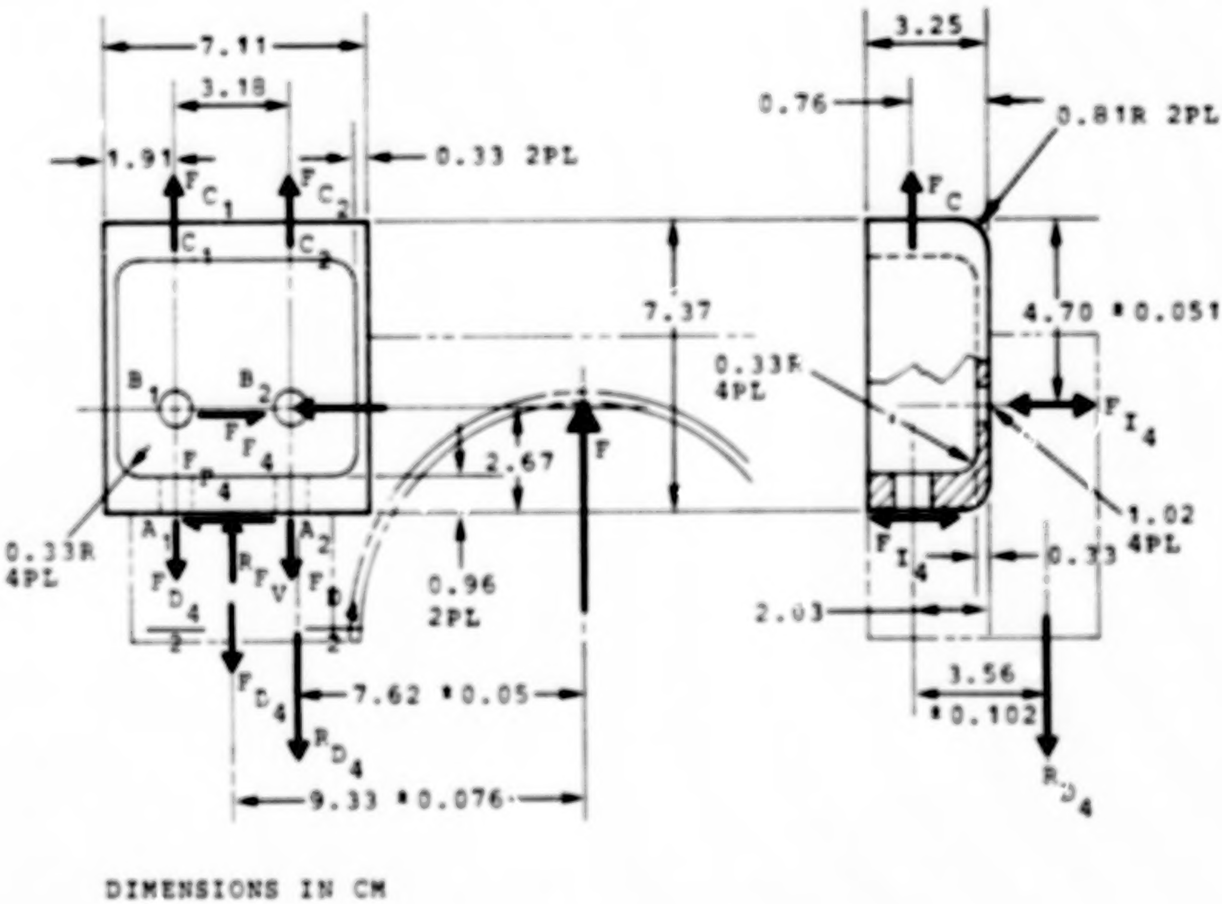
Analysis of Upper Clamp (41004819-004) (cont)

$$M.S._{YIELD} = \frac{57000(.85)}{29916} - 1 = \boxed{0.62}$$

$$\tau = \frac{F_4}{bt} = \frac{458.85715}{(1.08)(.48)} = 6101 \text{KPa} \; \underline{\underline{(885 \text{ psi})}}$$

$$M.S._{YIELD} = \frac{[38000(.91)](\frac{57}{67})}{885} - 1 = \boxed{\text{LARGE}}$$

Analysis of Bracket (41004819-006)



DIMENSIONS IN CM

Since we don't know which will react first, loads in bolts "A" or "B", we will use total loads in "A" first and then total loads in "B" next. (conservative).

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

Accumulator, Clamps & Brackets (cont)
Analysis of Bracket (41004819-006) (cont)

Loading Condition #1

$$F_{MAX} = .98182W_{FWD_2} = \begin{matrix}634.6N\\(142.66336\ lb)\end{matrix}$$

Reacted at bracket as:

$$R_{F_Y} = F_{MAX} = \begin{matrix}634.6N\\(142.66336\ lb)\end{matrix}$$ (comp. load into bracket)

$$R_{F_H} = \frac{(F_{MAX})(3.705)}{1.04} = \begin{matrix}2261N\\(508.23822\ lb)\end{matrix}$$ (shear load on bolts)

Loading Condition #2

$$R_{D_{4_{MAX}}} = .5W_{DOWN_2} + .12067[W_{INBD_1} + W_{INBD_2}] + .72817W_{FWD_2} = \begin{matrix}1877N\\(422.00053\ lb)\end{matrix}$$

$$R_{F_4} = .25[W_{FWD_1} + W_{FWD_2}] = \begin{matrix}302.7N\\(68.055\ lb)\end{matrix}$$

$$R_{I_4} = .25[W_{INBD_1} + W_{INBD_2}] = \begin{matrix}302.7N\\(68.055\ lb)\end{matrix}$$

Reacted at bracket as:

$$F_{D_4} = R_{D_4} = \begin{matrix}1877N\\(422.00053\ lb)\end{matrix}$$ (tension load on bolts "A" shear load on bolts "B")

$$F_{F_4} = R_{F_4} + \left(\frac{.675+.050}{1.05-.010}\right)R_{D_4} = \begin{matrix}1611N\\(362.23806\ lb)\end{matrix}$$ (shear load on bolts "A" & "B")

$$F_{I_4} = R_{I_4} + \left(\frac{1.40+.040}{1.05-.010}\right)R_{D_4} = \begin{matrix}2902N\\(652.36353\ lb)\end{matrix}$$ (tens. or comp. load on bolts "B" shear load on bolts "A")

It is obvious from the above information that loading condition #2 is the more severe of the two and will be used for anlysis.

41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)

Analysis of Bracket (41004819-006) (cont)

Bolts "A"

(each bolt) $\frac{1}{2}F_{D_4}$ (tension); $\overbrace{F_{F_4}\text{(shear)};\ F_{I_4}\text{(shear)}}^{\text{(assuming only 1 bolt reacts)}}$

$$\sigma_t = \frac{\frac{1}{2}(422.001)}{.0878} = \underline{\begin{matrix}1.657\times10^4\,\text{KPa}\\(2403\text{ psi})\end{matrix}}$$

$\frac{3}{8}$ -24 bolt

A_s (tensile stress area) = $0.566\,CM^2$ ($.0878\ in^2$)

$$\text{Total Shear Load} = \sqrt{(F_{F_4})^2 + (F_{I_4})^2} = \sqrt{(362.238)^2 + (652.363)^2} = \begin{matrix}3319N\\(746.186\text{ lb})\end{matrix}$$

$\frac{3}{8}$ -24 bolt

A(shear stress area) = $0.519\,CM^2$ ($.0809\ in^2$)

$$\tau = \frac{746.186}{.0809} = \underline{\begin{matrix}6.359\times10^4\,\text{KPa}\\(9224\text{ psi})\end{matrix}}$$

$$\sigma_{P_{MAX}} = \frac{\sigma_t}{2} + \sqrt{\left(\frac{\sigma_t}{2}\right)^2 + \tau^2} = \frac{2403}{2} + \sqrt{\left(\frac{2403}{2}\right)^2 + (9224)^2} = \underline{\underline{\begin{matrix}7.241\times10^4\,\text{KPa}\\(10503\text{ psi})\end{matrix}}}$$

$$\tau_{MAX} = \frac{1}{2}\sqrt{\sigma_t^2 + 4\tau^2} = \frac{1}{2}\sqrt{(2403)^2 + 4(9224)^2} = \underline{\underline{\begin{matrix}6.413\times10^4\,\text{KPa}\\(9302\text{ psi})\end{matrix}}}$$

Bolts "B"

(each bolt) $\overbrace{F_{D_4}\text{(shear)};\ F_{D_4}\text{(shear)}}^{\text{(assuming only 1 bolt reacts)}}$; $\frac{1}{2}F_{I_4}$ (tension)

$$\text{Total Shear Load} = \sqrt{F_{D_4}^{\ 2} + F_{F_4}^{\ 2}} = \sqrt{(422.001)^2 + (362.238)^2} = \begin{matrix}2474N\\(556.14855\text{ lb})\end{matrix}$$

$$\tau = \frac{556.149}{.0809} = \underline{\begin{matrix}4.740\times10^4\,\text{KPa}\\(6875\text{ psi})\end{matrix}}$$

41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)
Analysis of Bracket (41004819-006 (cont)

$$\sigma_t = \frac{\frac{1}{2}(652.363)}{.0878} = 2.561\text{x}10^4 \text{KPa} \quad \underline{(3715 \text{ psi})}$$

$$\sigma_{P_{MAX}} = \frac{\sigma_t}{2} + \sqrt{\left(\frac{\sigma_t}{2}\right)^2 + \tau^2} = \frac{3715}{2} + \sqrt{\left(\frac{3715}{2}\right)^2 + (6875)^2} = 6.190\text{x}10^4 \text{KPa} \quad \underline{\underline{(8979 \text{ psi})}}$$

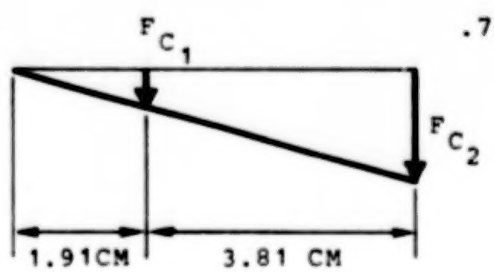
$$\tau_{MAX} = \frac{1}{2}\sqrt{\sigma_t^2 + 4\tau^2} = \frac{1}{2}\sqrt{(3715)^2 + 4(6875)^2} = 4.910\text{x}10^4 \text{KPa} \quad \underline{\underline{(7122 \text{ psi})}}$$

M.S. (either bolts "A" or "B") = $\boxed{\text{LARGE}}$

Bolts "C"

(direct tension loads) $F_{C_1} + F_{C_2} = F_{C_4} \longrightarrow F_{C_1} = F_{C_2} = .5F_{D_4}$

(tension due to moment caused by F_{F_4})



$.75F_{C_1} = 2.25F_{C_2}$

$F_{C_1} = 3F_{C_2}$

$$(\Sigma M) \quad .75F_{C_1} + 2.25F_{C_2} = 1.06F_{F_4}$$

$$.75F_{C_1} + 2.25\left(\frac{1}{3}F_{C_1}\right) = 1.06F_{F_4}$$

$$F_{C_1} = \frac{1.06F_{F_4}}{1.50} = .70667F_{F_4}$$

$$F_{C_2} = .23556F_{F_4}$$

41004640 - Landing Gear, Active Controls

Accumulator, Clapms & Brackets (cont)
Analysis of Bracket (41004819-006) (cont)

(max tension due to moment caused by F_{I_4} at "A") $F_{C_1}=F_{C_2}=\frac{1}{2}\left[\frac{2.91}{(1.22-.81)}(F_{I_4})\right]=3.54878F_{I_4}$

(total loads) (tension) $F_{C_1}=.5F_{D_4}+.70667F_{F_4}+3.54878F_{I_4}$

$=(.5)(422.001)+(.70667)(362.238)+(3.54878)(652.363)$

$=1.238\times10^4$N (2782.076 lb) (max tension)

$F_{C_2}=.5F_{D_4}+.23556F_{F_4}+3.54878F_{I_4}$

$=(.5)(422.001)+(.23556)(362.238)+(3.54878)(652.363)$

$=1.162\times10^4$N (2611.4221 lb)

(total loads) (shear) (assume only 1 bolt takes load) $F_{C_1}=F_{C_2}=\sqrt{F_{F_4}^2+F_{I_4}^2}=\sqrt{(362.238)^2+(652.363)^2}$

$=3319$N (746.1862 lb) (max shear)

The above are load requirements for attaching to aircraft structure (assume 2 attachments located approximately as shown on P. 83).

Top of Fitting

Use rectangular plate, 3 edges simply supported, 4th edge free, uniformly loaded. (Timoshenko, "Theory of Plates & Shells", P. 211-215).

$a=$ 7.11CM (2.80) $b=$ 3.10CM (1.22) $\frac{b}{a}=.43571$ $t_{MIN}=$ 9.4MM (.37 in)

$(M_x)_{MAX}=.060qa^2$ (table 42)

$q=\frac{F_{C_1}+F_{C_2}}{ab}=\frac{(2782.076)+(2611.422)}{(2.80)(1.22)}=1.089\times10^4$KPa (1578.8929 lb/in^2

41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)
Analysis of Bracket (41004819-006) (cont)

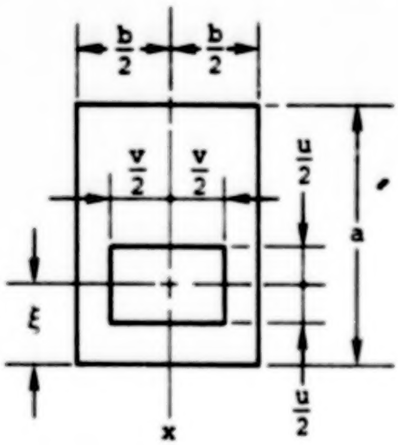
$$(M_x)_{MAX} = (.060)(1578.8929)(2.8)^2 = \begin{matrix}3304\text{N-M/N} \\ (742.7112 \text{ in lb/in})\end{matrix}$$

$$\sigma_b = \frac{6(M_x)_{MAX}}{t^2} = \frac{6(742.7112)}{.37^2} = \begin{matrix}2.244\times10^5 \text{KPa} \\ \underline{\underline{(32551 \text{ psi})}}\end{matrix}$$

$$M.S._{YIELD} = \frac{57000(.85)}{32551} - 1 = \boxed{0.49}$$

Back of Fitting

Use rectangular plate, 4 edges simply supported, load uniformly distributed over rectangular area (Timoshenko, "Theory of Plates & Shells, P. 158-161).



$$\underbrace{a = \begin{matrix}7.37\text{CM} \\ (2.90 \text{ in})\end{matrix} \quad u = \begin{matrix}2.54\text{CM} \\ (1.00 \text{ in})\end{matrix} \quad b = \begin{matrix}7.11\text{CM} \\ (2.80 \text{ in})\end{matrix} \quad v = \begin{matrix}5.08\text{CM} \\ (2.00 \text{ in})\end{matrix}}_{\text{(conservative)}} \qquad \nu = .33 \quad \xi = 1.04$$

$$t_{MIN} = \begin{matrix}.305\text{CM} \\ (.12 \text{ in})\end{matrix} \quad \frac{b}{a} = .96552 \quad k = \frac{v}{u} = 2.00$$

$$\frac{\xi}{a} = .35862 \quad d = \sqrt{u^2+v^2} = 2.236$$

(from table 26) $\varphi = 1.481$, $\psi = .374$ (from table 27) $\lambda = 2.6964$, $\mu = .110$

$$P = F_{I_4} = \begin{matrix}2902\text{N} \\ (652.363 \text{ lb})\end{matrix}$$

$$M_x = \frac{P}{8\pi}\left[((2)\ln(\frac{4a \sin\frac{\pi\xi}{a}}{\pi d}) + \lambda - \varphi)(1+\nu) + (\mu+\psi)(1-\nu)\right]$$

$$M_x = \frac{652.363}{8\pi}\left[((2)\ln(\frac{4(2.90) \sin\frac{\pi(1.04)}{2.90}}{\pi(2.236)}) + 2.6964 - 1.481)(1.33) + (.110+.374)(.67)\right]$$

Accumulator, Clamps & Brackets (cont)
Analysis of Bracket (41004819-006) (cont)

Back of Fitting (cont)

$$M_x = (25.95670)\left[((2)\ln(1.49111) + 2.6964 - 1.481)(1.33) + .32428\right]$$

$$M_x = \frac{346.8\text{N-M/M}}{(77.96088\text{ in-lb/in})}$$

$$M_y = \frac{P}{8\pi}\left((2)\ln\left(\frac{4a\ \mathrm{Sin}\ \frac{\pi\xi}{a}}{\pi d}\right) + \lambda - \varphi\right)(1+\nu) - (\mu+\psi)(1-\nu)$$

$$M_y = (25.95670)\left[(.79905 + 2.6964 - 1.481)(1.33) - .32428\right] = \frac{271.9\text{N-M/M}}{(61.12641\text{ in-lb/in})}$$

$$\sigma_x = \frac{6M_x}{t^2} = \frac{6(77.96088)}{.12^2} = \frac{2.239\times10^5\text{KPa}}{(32483\text{ psi})}$$

$$\text{M.S.}_{\text{YIELD}} = \frac{57000(.85)}{32483} - 1 = \boxed{.49}$$

Compression Buckling

The only way for above bracket to be in compression is for R_{D_4} to be "up" instead of "down".

$$R_{D_4} = .5W_{UP_2} + .12067\left[W_{INBD_1} + W_{INBD_2}\right] + .72817W_{FWD_2} \text{ (Ref. P. 78)}$$

$$R_{D_4} = (.5)(203.427) + (.12067)\left[126.915 + 145.305\right] + (.72817)(145.305)$$

$$= \frac{1069\text{N}}{(240.36903\text{ lb})}$$

$$F_{D_4} = \frac{1069\text{N}}{(240.369\text{ lb})}$$

41004640 - Landing Gear, Active Controls

Accumulator, Clamps & Brackets (cont)
Analysis of Bracket (41004819-006) (cont)

Compression Buckling (cont)

$$F_{F_4} = 68.055 + \left(\frac{.675+.050}{1.05-.010}\right)(240.369) = \begin{matrix}1048N \\ (235.620\ lb)\end{matrix}$$

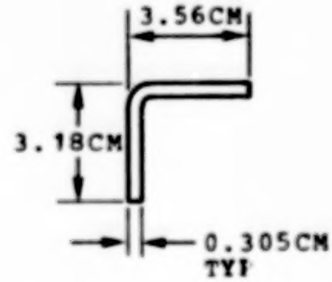
$$F_{I_4} = 68.055 + \left(\frac{1.40+.040}{1.05-.010}\right)(240.369) = \begin{matrix}1783N \\ (400.874\ lb)\end{matrix}$$

(from P. 84)

Less than loads on P.84 - Do not need to analyze shears.

$$\text{Total Compression Load} = R_{F_V} + F_{D_4} = 142.663 + 240.369 = \begin{matrix}1726N \\ (383.032\ lb)\end{matrix}$$

Crippling allowable (Bruhn, Page C7.1)



$$\frac{a+b}{2t} = \frac{1.25+1.40}{2(.12)} = 11.042$$

(from Fig. C7.3) $\dfrac{F_{cc}}{\sqrt{F_{c_y} E}} = .057$ (one edge free)

$$F_{cc} = .057\sqrt{F_{c_y} E} = .057\sqrt{(57000)(.85)(10.3\times10^6)} = \begin{matrix}2.776\times10^5\ KPa \\ (40266\ psi)\end{matrix}$$

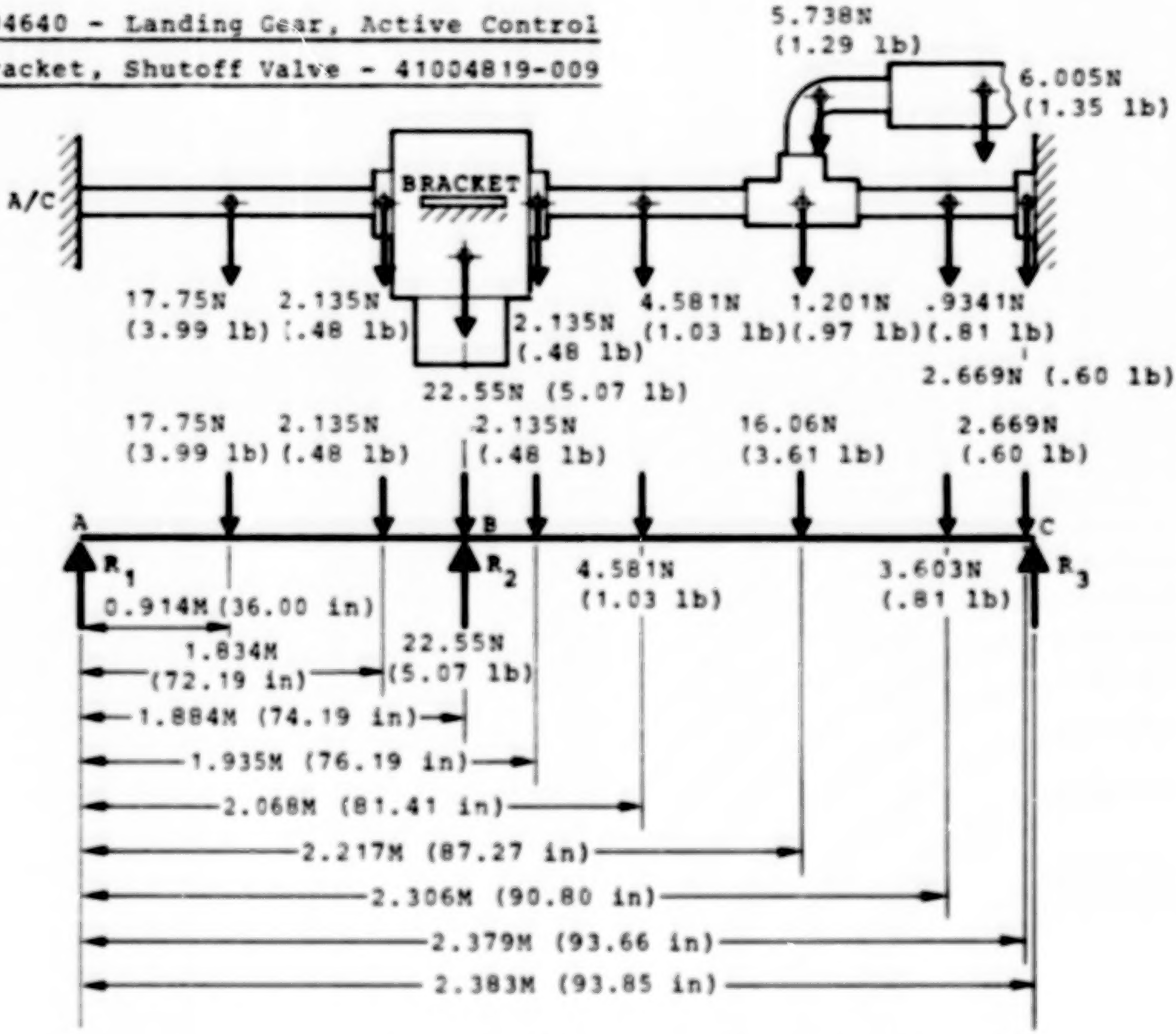
$$\text{Area} = \left[2.80+2(1.25)\right](.12) = \begin{matrix}4.1CM^2 \\ (.636\ in^2)\end{matrix}$$

$$\sigma_c = \frac{383.032}{.636} = \begin{matrix}4150KPa \\ (602\ psi)\end{matrix}$$

$$M.S. = \frac{40266}{602} - 1 = \boxed{\text{LARGE}}$$

41004640 - Landing Gear, Active Control

Bracket, Shutoff Valve - 41004819-009



$$M_A L_1 + 2M_B(L_1+L_2) + M_C L_2 = -\Sigma \frac{P_{1i}a_{1i}b_{1i}(L_1+a_{1i})}{L_1} - \Sigma \frac{P_{2i}a_{2i}b_{2i}(L_2+b_{2i})}{L_2}$$

$$\cancelto{0}{M_A}(74.19) + 2M_B(74.19+19.66) + \cancelto{0}{M_C}(19.66) = -\frac{(3.99)(36.00)(38.19)(74.19+36.00)}{74.19}$$

$$-\frac{(.48)(72.19)(2.00)(74.19+72.19)}{74.19} - \frac{(.48)(2.00)(17.66)(19.66+17.66)}{19.66}$$

$$-\frac{(1.03)(7.22)(12.44)(19.66+12.44)}{19.66} - \frac{(3.61)(13.08)(6.58)(19.66+6.58)}{19.66}$$

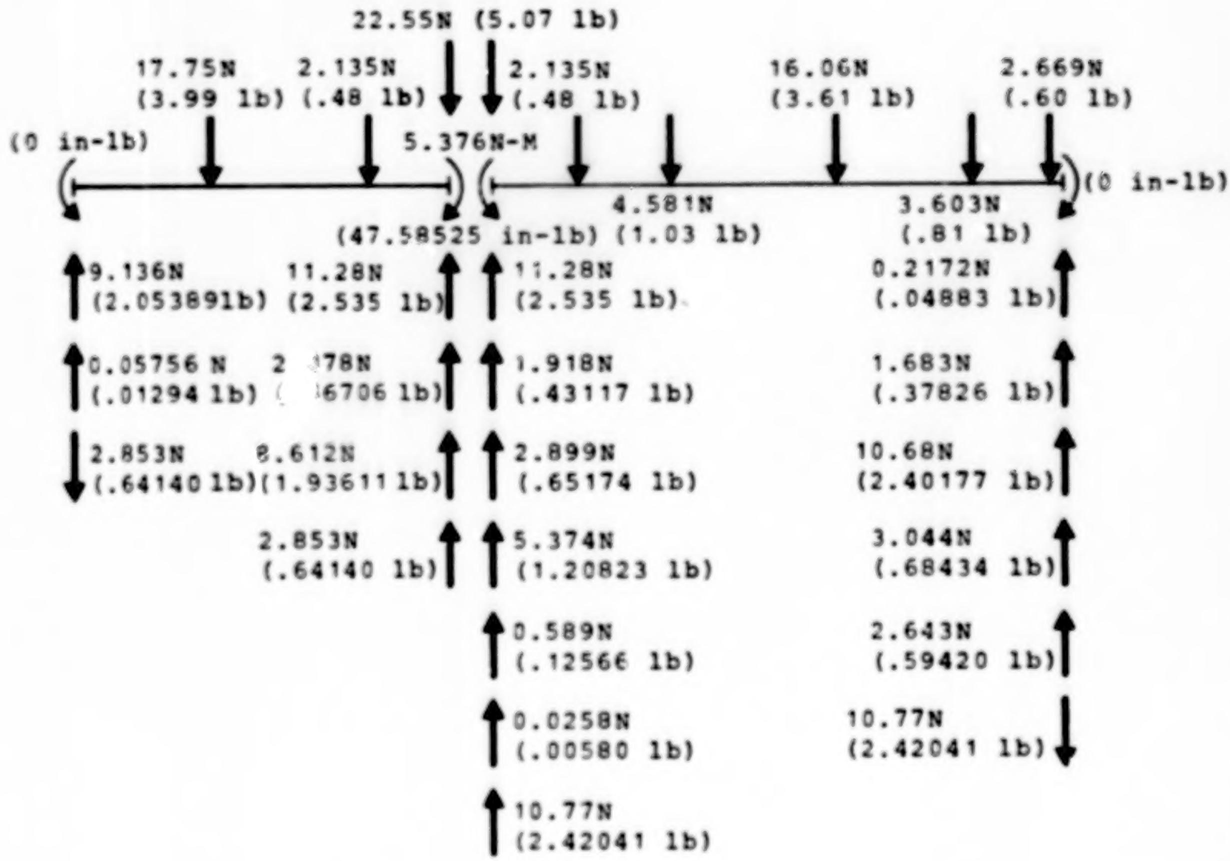
$$-\frac{(.81)(16.61)(3.05)(19.66+3.05)}{19.66} - \frac{(.60)(19.47)(.19)(19.66+.19)}{19.66}$$

$$187.7M_B = -8147.4531 - 136.73656 - 32.18252 - 151.04847 - 414.6877 - 47.40107 - 2.24103 = -8931.7504$$

$$M_B = \begin{array}{l} -5.376\text{N-M} \\ (-47.58525 \text{ in-lb}) \end{array}$$

41004640 - Landing Gear, Active Control

Bracket, Shutoff Valve - 41004819-009 (cont)



$R_1 = \begin{matrix}6.340N\\(1.42543\ lbs)\end{matrix}$ $R_2 = \begin{matrix}57.64N\\(12.95758\ lbs)\end{matrix}$ $R_3 = \begin{matrix}7.504N\\(1.68699\ lbs)\end{matrix}$

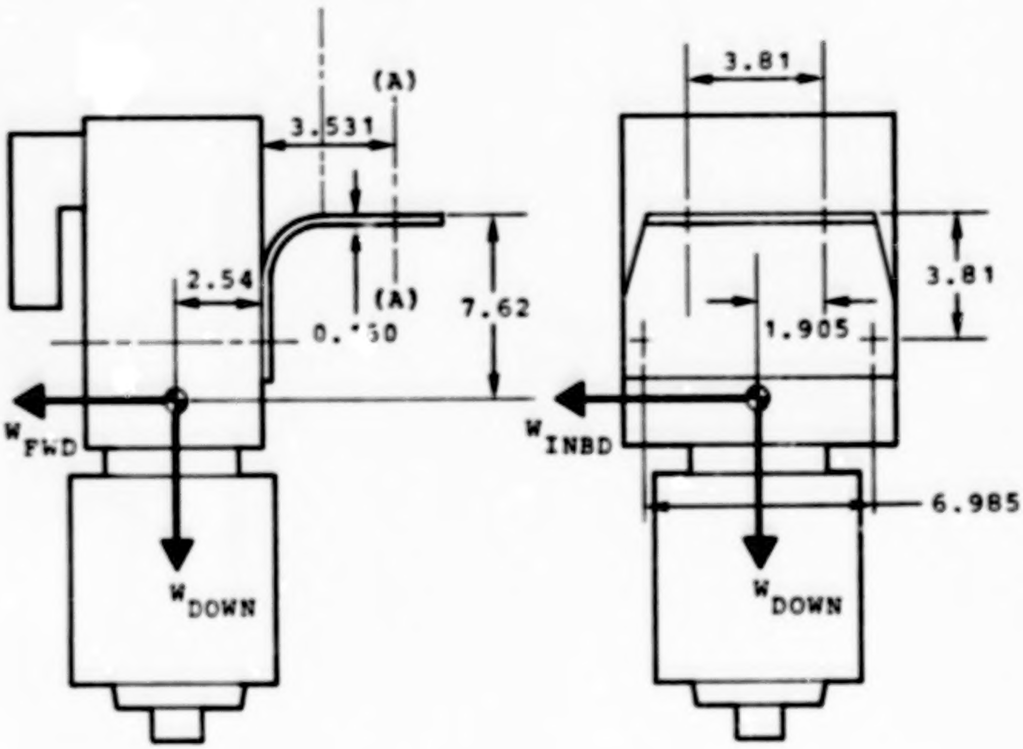
(check) $R_1+R_2+R_3=16.07=3.99+.48+5.07+.48+1.03+3.61+.81+.60$

$\therefore$ max Wt on bracket $\approx \begin{matrix}57.65N\\(12.96\ lb)\end{matrix}$

This Wt combined with the required "g" factors will determine max loading conditions to analyze bracket.

41004640 - Landing Gear, Active Controls

Bracket, Shutoff Valve - 41004819-009 (cont)



DIMENSIONS IN CM

$W_{FWD}=W_{AFT}=1.5R_2=\frac{86.47N}{(19.44\ lb)}$

$W_{DOWN}=5.85R_2=\frac{337.3N}{(75.82\ lb)}$

$W_{UP}=2.1R_2=\frac{121.1N}{(27.22\ lb)}$

$W_{INBD}=W_{OUTBD}=1.5R_2=\frac{86.47N}{(19.44\ lb)}$

(moment at (A)-(A)) $M_{(A)}=2.39W_{DOWN}+3.00W_{AFT}=\frac{27.06N\text{-}M}{(239.53\ in\text{-}lb)}$

$b=2.32-(2x.50)=\frac{3.353CM}{(1.32\ in)}$ $t=\frac{.160CM}{(.063\ in)}$

$$\sigma_b=\frac{6M_{(A)}}{bt^2}=\frac{6(239.53)}{(1.32)(.063)^2}=\frac{1.891x10^6 KPa}{\underline{(274319\ psi)}}$$

41004640 - Landing Gear, Active Controls

Bracket, Shutoff Valve - 41004819-009 (cont)

$$T_{(A)} = 3.00W_{INBD} = (3.00(19.44) = \begin{matrix} 6.589N\text{-}M \\ (58.32\ \text{in-lb}) \end{matrix}$$

$$\tau_{MAX} = \frac{3T_{(A)}\left[1+.6\ \frac{t}{b}\right]}{bt^2} = \frac{3(58.32)\left[1+.6\ \frac{.063}{1.32}\right]}{(1.32)(.063)^2} = \begin{matrix} 2.368\times10^5\,KPa \\ (34351\ \text{psi}) \end{matrix}$$

This is not a structural part. For location purposes only. To make part structural, see below.

$$t = \sqrt{\frac{6M_{(A)}}{\sigma_b b}} = \sqrt{\frac{6(239.53)}{(35000)(.88)(1.32)}} = \begin{matrix} .477CM \\ (.188\ \text{in}) \end{matrix}$$

To be structural, bracket must be either $\sim \begin{matrix} .508CM \\ (.20\ \text{in}) \end{matrix}$ thick or must be designed to include side gussets capable of taking sufficient compression load.

APPENDIX B

SYSTEM SPECIFICATION

DESIGN SPECIFICATION, FLIGHTWORTHY ELECTRO-HYDRAULIC ACTIVE CONTROL LANDING GEAR SYSTEM FOR A SUPERSONIC AIRPLANE

1.0 SCOPE

This document establishes the requirements and defines the design objectives for an electro-hydraulic active control landing gear system for a supersonic aircraft, based on a modified landing gear.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent that they are applicable:

Contract NAS1-15455 issued by NASA Langley Research Center, Hampton, Virginia

MIL-STD-810C - Environmental Test Methods

MIL-STD-461 - Electromagnetic Interference Characteristics

MIL-E-5400 - Electrical Equipment, Airborne General Specification

MIL-STD-454 - Standard General Requirements for Electronic Equipment

MIL-STD-275 - Printed Wiring for Electronic Equipment

QQ-A-325 - Aluminum Alloy Sheet

MIL-S-19500/X - Semiconductor Devices, General Specification

MIL-S-5541 - Chemical Film Finishes

MIL-G-5514 - Packings, Installation and Gland Design Hydraulic, General Specification for

MIL-I-6866 - Inspection, Penetrant Methods of

MIL-S-8879 - Screw Threads, Controlled Radius Root with Increased Minor Diameter, General Specification for

MIL-I-6868 - Inspection Process, Magnetic Particle

MIL-H-27601 - Hydraulic Fluid, Petroleum Base High Temperature, Flight Vehicle

MIL-R-83248 - Type, Class 1 Rubber, Fluorocarbon Elastomer High Temperature Fluid and Compression Set Resistant O-Ring

MS33540 - Safety Wiring and Cotter Pinning, General Practices for

MS33649 - Bosses, Fluid Connection Internal Straight Thread

Other Publications

For requirements not covered above, materials, processes, and standard products shall be selected in accordance with specifications or standards from the sources indicated below and in the order of precedence shown:

1. Federal specifications and standards as listed in the Index of Federal Specifications, Standards and Handbooks published by the General Services Administration.

2. Military specifications and standards as listed in the Department of Defense Index of Specifications and Standards.

3. Industry Specifications and standards as listed in indexes published by recognized industrial associations including, but not limited to, the following without order of precedence:

   a. National Aerospace standards (NAS) as published by the National Aircraft Standards Committee of the Aerospace Industries Association.

   b. Aerospace Materials standards (AMS), Aerospace Standards (AS), Aerospace Recommended Practices (ARP) and Aerospace Information Reports (AIR) published by the Society of Automotive Engineers.

3.0 REQUIREMENTS

The active control landing gear system shall be designed in accordance with the requirements of this specification. The equipment shall meet the performance requirements when installed on the aircraft during conditions of landing, taxi, and take-off, and under the conditions of paragraph 3.1.2.1.

3.1 System Function and Definitions

3.1.1 System Function

The ACLG shall operate as a closed loop to command the wing gear interface force to the level of the generated limit force.

3.1.2 Item Definition (Figure B-1)

The active control main landing gear system (ACLG) of the supersonic airplane is a dual system, each set of which consists of a modified strut, a servovalve, an accumulator, an electronic controller, cockpit-mounted sink rate selector, and interface hardware tieing into existing hydraulic and electrical supply systems, and into existing aircraft mounted sensors, all of which are defined in 3.1.2.2.

3.1.2.1 System Conditions

The ACLG shall meet its performance requirements when the system parameters are as follows:

Charging Gas	GN2
Fully compressed gas volume	$7.375 \times 10^{-4} m^3$ (45 in^3)
Gas pressure, extended (70°F)	1930 KPa. (280 PSIG)
Oil volume (MIL-H-27601A)	$0.0156 m^3$ (952 in^3)
Strut Stroke	0.508m (20 ins.)
Maximum oil temperature	121°C (250°F)
Minimum oil temperature	-40°C (-40°F)
Design landing load	$1.512 \times 10^5 N$ (34,000 lbs)
Design maximum sink rate	3.048m/sec (10 ft/sec)
Maximum landing load	$2.335 \times 10^5 N$ (52,500 lbs)
Tire pressure (unloaded)	2758KPa (400 psig)
Touch down velocity	93.27m/sec (306 ft/sec)
Unsprung weight	3892N (875 lbs)
Wheel well temperature	-54 to 121°C (-65° to 250°F)
Gear position	down at all times

3.1.2.2 Associated Sensors

Wing/Gear Accelerometers

Range	-	± 4.12 g's
Scale factor	-	0.002 v/g @ 5vdc excitation

Strut Hydraulic Pressure Transducer

Range	-	$0\text{-}1.72 \times 10^4$ KPa. (0-2500 psi)
Scale factor	-	0.00232 mv/KPa (0.016 mv/psi)

Strut Stroke Transducer

Type	-	Synchro
Range	-	$\pm$ 0.254m ($\pm$ 10 ins.)
Scale Factor	-	19.69 VRMS/m (0.5 VRMS/in.)

Scissors Switch

Type	-	open or closed (takeoff or landing mode indicator)

Wheel Generator

Type	-	D.C. generator
Range	-	0-2400 rpm (156 knots)
Scale Factor	-	19.6 mv/rpm

3.1.3 Interface Definition

The landing gear system shall be capable of operation when system parameters are as listed below, when powered by the existing aircraft hydraulic and electrical systems, and when interconnected with cockpit controls and aircraft mounted sensors as listed in paragraph 3.1.2.2.

3.1.3.1 Hydraulic System

The ACLG shall meet the requirements of this specification when used with an aircraft hydraulic system which is capable of supplying a pressure of 2.31×10^{-4} kPa (3350 psig) and a maximum flow to 8.194×10^{-4} m^3/min. To provide the required transient flow the ACLG shall incorporate a $0.0265m^3$ (7 gallon) accumulator for each of the two landing gear struts.

3.1.3.2 Electrical System

The electrical power available on the aircraft consists of 28vdc, 26vrms, 400 Hz, and 115 vrms, 400 Hz in accordance with MIL-STD-704A.

3.7 COCKPIT CONTROLS AND INDICATORS

The cockpit control panel shall include a power switch, a sink rate selector (to be used in lieu of a sink rate sensor), a test button and status indicator lamps.

3.2 STRUT REQUIREMENTS

The following sections define the configuration and requirements of the landing gear struts.

3.2.1 Strut Modifications

The struts shall be modified so that the hydraulic chambers at the lower end of the strut will connect to the control port of the servovalve thereby allowing the servovalve to port hydraulic fluid into or out of the strut as required to control the wing gear interface force. The basic gear structure shall remain intact.

3.2.2 Materials

Materials used shall be in accordance with the applicable military specifications and shall be compatible with those in the aircraft and landing gear.

3.2.3 Pressure

The hydraulic pressure in the strut shall not exceed 2200 psi. Relief valves shall be used to meet this requirement.

3.2.4 Installation Hardware

Hardware such as supporting brackets for hydraulic lines shall be installed in the wheel well at locations agreed to by the aircraft manufacturer.

3.3 ACCUMULATORS

Accumulators shall be used for each strut to supply the necessary transient flow.

3.3.1 Volume

The total volume of the accumulator for each strut shall be $0.0265\,m^3$ (7 gallons).

3.3.2 Location

The accumulators shall be installed in the aircraft wheel well in a manner approved by the aircraft manufacturer.

3.4 SERVOVALVE

A servovalve shall be used for each strut and shall meet the following requirements.

3.4.1 Performance

The performance requirements are shown in the Appendix

3.4.2 Envelope

The servovalve envelope is shown in HR drawing 23241510

3.5 CONTROLLER

The controller shall be used as an integral part of the closed-loop servosystem which controls the aircraft wing/gear interface force during landing, taxi, and take-off. The controller shall accept sensor data, perform computations involving energy and momentum, effect prescribed control laws and provide an output current to the servovalve.

The controller shall also contain the electronic circuitry necessary to test the system for failures and cause a reversion to a passive gear configuration if a failure exists.

3.5.1 Requirements

3.5.1.1 Input-Output Requirements

The input/output signal requirements are shown in block diagram form in Figure B-2. Primary inputs and outputs are those signals required to perform the control function. Secondary inputs and outputs are those signals used for testing and status indication but which do not influence the control function. Figure B-3 defines the sign conventions and transducer polarities.

3.5.1.1.1 Primary Input Signals

The primary input-output signals shall be those shown in TABLE B-I.

3.5.1.1.2 Secondary Input-Output Signals

Secondary input-output signals shall be as specified in TABLE B-II and B-III respectively.

3.5.1.2 Functional Controller Requirements

The controller shall have three basic functional requirements as shown in Figure B-4. These are:

1. Operating mode determination,
2. Charging pressure regulation and limit force command determination,
3. Control law implementation

3.5.1.2.1 Operating Mode Determination

The controller establishes the operating modes of the active control landing gear system upon application of electrical power and through its acceptance of condition states from sensors (3.1.2.2).

The controller's "state" is defined in terms of "enable function" and "modes".

3.5.1.2.1.1 Enable Functions

The enable functions of the system (controller) are "Controller Enable" "Servoloop Enable", and "Integrator Enable".

3.5.1.2.1.1.1 Controller Enable

"Controller-Enable" is defined as that condition which allows the controller to perform calculations. This condition occurs when power is applied and the test confirms system integrity.

3.5.1.2.1.1.2 <u>Servoloop Enable</u>

"Servoloop Enable" is defined as that condition which allows the controller to provide current to the servovalve coil. Under landing conditions, "Servoloop Enable" occurs when the kinetic energy of the aircraft equals the work potential of the strut. Under take-off or taxi conditions it occurs upon application of power.

3.5.1.2.1.1.3 <u>Integrator Enable</u>

"Integrator Enable" is defined as that condition which allows the integrator, which generates the wing-gear velocity from the wing-gear acceleration, to function. It occurs at touchdown. This enabling function is necessary in order to prevent integrator drift.

3.5.1.2.1.2 <u>Modes</u>

The modes of the system (controller) are "Landing", "Take-off" and "Test"

3.5.1.2.1.2.1 <u>Landing Mode</u>

The landing mode is selected by the controller when power is applied,the scissors switch is open and a successful test has been completed. The controller shall then commence computation of kinetic energy and strut work potential in the manner shown in Figure B-5. The controller shall not enable the servoloop until the kinetic energy is less than the work potential of the strut.

The landing mode encompasses several phases, each imposing a different functional demand on the controller. These phases are:

1. passive phase
2. impact active control
3. transition
4. rollout and taxi

3.5.1.2.1.2.1.1 Passive Phase

In the passive phase the controller shall:

1. Close an auxilliary pressure loop to maintain the strut pressure at its charging value.
2. Compute kinetic energy of the aircraft, work potential of the strut and compare these values.
3. Sample and hold value of the wing-gear interface force (wing-gear acceleration).

3.5.1.2.1.2.1.2 Impact Active Control

The impact active control phase shall commence when the energy comparison indicates that the work potential of the strut equals or exceeds the kinetic energy of the aircraft. Upon such occurrence the controller shall:

1. enable the servoloop
2. discontinue energy computations
3. maintain a constant limit force
4. deliver a current to the servovalve in accordance with the control laws
5. calculate the velocity at which transition is to commence, in accordance with the relationships shown in Figure B-6, and compare this to the actual velocity to determine the starting point of transition.

3.5.1.2.1.2.1.3 Transition

The transition to the rollout phase shall commence when the wing/gear interface velocity becomes equal to the transition velocity. During transition the controller shall:

1. Linearly decrease the limit force command to a predetermined minimum force (F_{min}).

2. Maintain active control about F_{min} as long as F_{wg} is greater than F_{min} or less than $-F_{min}$.

3. Set the limit force command to zero and disable the force loop when F_{wg} becomes less than F_{min}.

3.5.1.2.1.2.1.4 Rollout and Taxi

The rollout phase shall commence when the limit force command in the transition phase reaches zero. During the rollout phase the controller shall maintain active control with the limit force command equal to F_{min} as long as F_{wg} is greater than F_{min} or F_{wg} is less than $-F_{min}$. For values of F_{wg} less than F_{min} or greater than $-F_{min}$, the limit force command shall be set to zero and the force loop disabled. The controller shall remain in the rollout mode until takeoff occurs or power is removed.

3.5.1.2.1.2.2 Takeoff Mode

The controller shall automatically select the takeoff mode of operation when:

1. Power has been applied.
2. The scissors switch is closed.

During takeoff the limit force command shall be zero and active control maintained about this limit force command.

3.5.1.2.2 Limit Force Command Computation

The limit force shall be the command to the servoloop and shall serve as the desired wing/gear interface force. The limit force command shall be generated according to the requirements of each mode and phase as described below.

3.5.1.2.2.1 Landing Mode

3.5.1.2.2.1.1 Passive Phase

Commencing with controller enablement and continuing until the servoloop is enabled the effective limit force command shall be zero.

3.5.1.2.2.1.2 Impact Active Control Phase

From the time the servoloop is enabled until the start of the transition phase the limit force command shall be constant, and equal to the value of the wing/gear interface force at the time the servoloop is enabled.

3.5.1.2.2.1.3 Transition

The limit force shall linearly decrease at a specified rate, as shown in Figure B-7, from its value at the start of transition to F_{min} at which time F_{LC} will be set to zero and the force loop disabled.

3.5.1.2.2.1.4 Rollout and Taxi

During the rollout and taxi phase the limit force command shall be zero or $\pm F_{min}$.

3.5.1.2.2.2 Limit Force Command - Takeoff Mode

In the takeoff mode of operation the limit force command shall be zero.

3.5.1.2.3 Control Laws

The controller shall implement the control laws shown in Figure B-8 and the transfer functions of TABLE B-IV.

3.5.1.2.4 Position Loop

The ACLG shall incorporate a low response position loop for the purpose of returning the strut to its static position during the rollout phase of the landing.

3.5.1.2.5 Auxiliary Pressure Loop

An auxiliary pressure loop shall be incorporated for the purpose of setting and maintaining the static hydraulic pressure of the gear. Whenever the servoloop is enabled the ausiliary pressure loop shall be disabled.

3.5.1.2.6 Dynamic Requirements

The loops of the ACLG shall meet the dynamic requirements of this section.

3.5.1.2.6.1 Force Loop

The force loop shall meet the following requirements:

Amplitude: Flat, to within 3 db, to TBD. Peaking shall not exceed 3 db.

Phase: Not to exceed 90° lag at TBD.

3.5.1.2.6.2 Position Loop

The position loop shall meet the following requirements when operating with the force loop closed:

Peaking frequency: approximately 0.1 Hz, peaking not to exceed 5 db.

Phase: approximately 90° lag at the peaking frequency.

These parameters are not critical.

3.5.2 Design (See Schematic, Figure B-9)

The controller shall be designed to meet all the requirements of this specification and shall provide safe and reliable operation.

3.5.2.1 Computational and Control Law Implementation

All computations and implementation of transfer functions shall be accomplished by means of analog circuitry in order to minimize the physical size of the controller and to optimize the controller response.

3.5.2.1.1 Limit Force Command

The limit force command signal shall be the wing-gear interface force during the passive phase. This signal shall be applied to a sample and hold circuit, but since the servoloop is disabled during the passive phase the effective limit force command is zero. At the start of the impact active control phase, the input to the sample circuit shall be disconnected thus holding the limit force command signal constant at the last sampled value of the wing-gear interface force. During the transition phase the hold circuit shall decay in a linear manner to decrease the limit force command to a preset minimum force (F_{min}) and for values of the wing-gear interface force less than F_{min} or greater then $-F_{min}$ the limit force command shall be set to zero.

3.5.2.1.2 Wing Gear Velocity Computation

The wing gear velocity signal shall be generated by integration of the signal from the wing/gear accelerometer. Means shall be provided for enabling the integrator at the time the controller is enabled and disabling it when the controller is disabled.

3.5.2.1.3 Energy Computations

3.5.2.1.3.1 Kinetic Energy of the Aircraft

The signal representing kinetic energy of the aircraft shall be computed by mathematically squaring the wing/gear interface velocity signal by means of an analog multiplier and attenuating it by one half as shown in Figure B-10.

3.5.2.1.3.2 Work Potential of the Strut

The signal representing work potential of the strut shall be computed by subtracting the strut stroke signal from a constant signal representing maximum stroke and multiplying this signal by the wing/gear acceleration signal, using an analog multiplier as shown in Figure B-10.

3.5.2.1.4 Transition Velocity Computation

The transition velocity shall be computed by using an analog multiplier to mathematically square the signal representing the limit force command during the impact active control phase, and attenuating it by a constant which represents the reciprocal of the product of twice the aircraft mass per gear and the transition decay rate (R) as shown in Figure B-10.

3.5.2.2 Comparisons

Comparisons for mode, phase determination and failure detection shall be accomplished by analog comparators driving analog switches.

3.5.2.3 Servovalve Driver

The power stage of the controller shall be capable of supplying ± 50 ma into a 200 ohm load. It's output impedance shall exceed 100 kilohms.

3.5.2.4 Controller Inputs (See Figure B-11)

3.5.2.4.1 Initial Sink Rate

The controller shall be so designed that it can accept a signal from a sink rate sensor or a signal from a variable source representing sink rate which is set by a control on the front panel of the controller or a control in the cockpit.

3.5.2.4.2 Servovalve Bias

The servovalve bias command shall be generated by a control which shall be capable of providing a DC voltage of 0 to ± 10VDC.

3.5.2.4.3 Strut Position Command

The strut position command as indicated in Figure B-8 shall be derived from a control which is capable of providing a DC voltage of 0 to ± 10 VDC. This signal determines the static position of the strut.

3.5.2.4.4 Strut Position Bias Signal

The strut position bias signal, as indicated in Figure B-8, shall be variable from 0 to $\pm$ 10 VDC. It is required in order to produce a null signal when the strut is at its design static deflection.

3.5.2.4.5 Sensor Inputs

The controller shall accept inputs from the following sensors:

Wing/gear accelerometer

Strut position sensor

Strut hydraulic pressure transducer

Characteristics of the signals shall be as described in

3.5.2.4.6 Wing/Gear Accelerometer Bias Signal

The wing/gear accelerometer bias signal as indicated in Figure B-9, shall be variable from 0 to ± 10 volts. It is required to produce a null signal when the accelerometer is mounted to output a signal equivalent to a positive one G-unit.

3.5.2.4.7 Top Panel Test Inputs

Provisions shall be included for inserting test signals into the controller by means of top panel jacks as shown in Figure B-12

3.5.2.5 Front Panel Outputs (See Figure B-13)

Buffered test outputs shall be available at front panel jacks as shown in Figure B-12.

3.5.2.6 Rear Panel

The rear panel of the controller shall contain the connectors, suitably labeled, as shown in Figure B-14.

3.5.2.7 Servovalve Current

The controller shall provide an output current to the servovalve. The characteristics of the servovalve driver shall be as defined in paragraph 3.5.2.3.

3.5.2.8 Flight Safety

The controller shall incorporate means for augmenting the safety of the aircraft as defined in the following paragraphs.

3.5.2.8.1 Built-in Test

The controller shall incorporate means for determining the functional integrity of the system prior to landing or take-off. The test shall consist of the following:

3.5.2.8.1.1 Pre-Land

When a cockpit mounted test button is depressed a simulated acceleration (wing/gear force) and strut compression shall be applied to the controller. The servovalve stroke signal shall be compared to the required signal at a point in time when the limit force command is approximately half-way down the ramp during the transition phase. A difference in these signals, in excess of a threshold value shall constitute a failure. Otherwise a green "Test in Progress" lamp in the cockpit shall be illuminated during the test and extinguished upon successful completion of the test.

3.5.2.8.1.2 Accelerometers

The accelerometer shall be tested by monitoring the output to determine if its signal is in the range of 0 g's. An incorrect signal shall constitute a failure.

3.5.2.8.1.3 Strut Stroke Transducer (Synchro)

The synchro circuitry shall incorporate a self-test feature to detect failures. It shall be accomplished by applying a voltage across the unused winding and each of the used windings and determining if a current flows.

3.5.2.8.1.4 Auxiliary Pressure Loop

The auxiliary pressure loop shall be tested by monitoring the loop error. A signal in excess of a threshold value which exists for a fixed amount of time shall constitute a failure.

3.5.2.8.2 Passive Reversion

An indication of any failure, as described in paragraph 3.5.2.8.1 in either channel shall cause currents to be latched out from both servovalves which will cause the spool centering springs to null the valves and energize a solenoid valve to prevent flow into or out of the struts. An amber light in the cockpit shall be illuminated to indicate that the gear is in a passive state.

3.5.2.9 Power Section

The power section shall accept 115 V RMS 400 Hz, 26 V RMS, 400 Hz and 28 VDC power from the aircraft power system and shall generate the DC voltages necessary for controller operation as shown in Figure B-15.

3.5.2.10 External Electrical Connectors

Connectors used for interconnection with the transducers, servovalves, and cockpit signals shall be arranged as shown in Figure B-16.

3.5.2.11 Parts

Electronic parts used in the controller shall be of military specification quality.

3.5.2.12 Packaging

The controller shall be contained within a single enclosure suitable for mounting in the electronics bay of the aircraft. Modular construction shall be employed to the extent necessary to provide easy access for maintenance purposes.

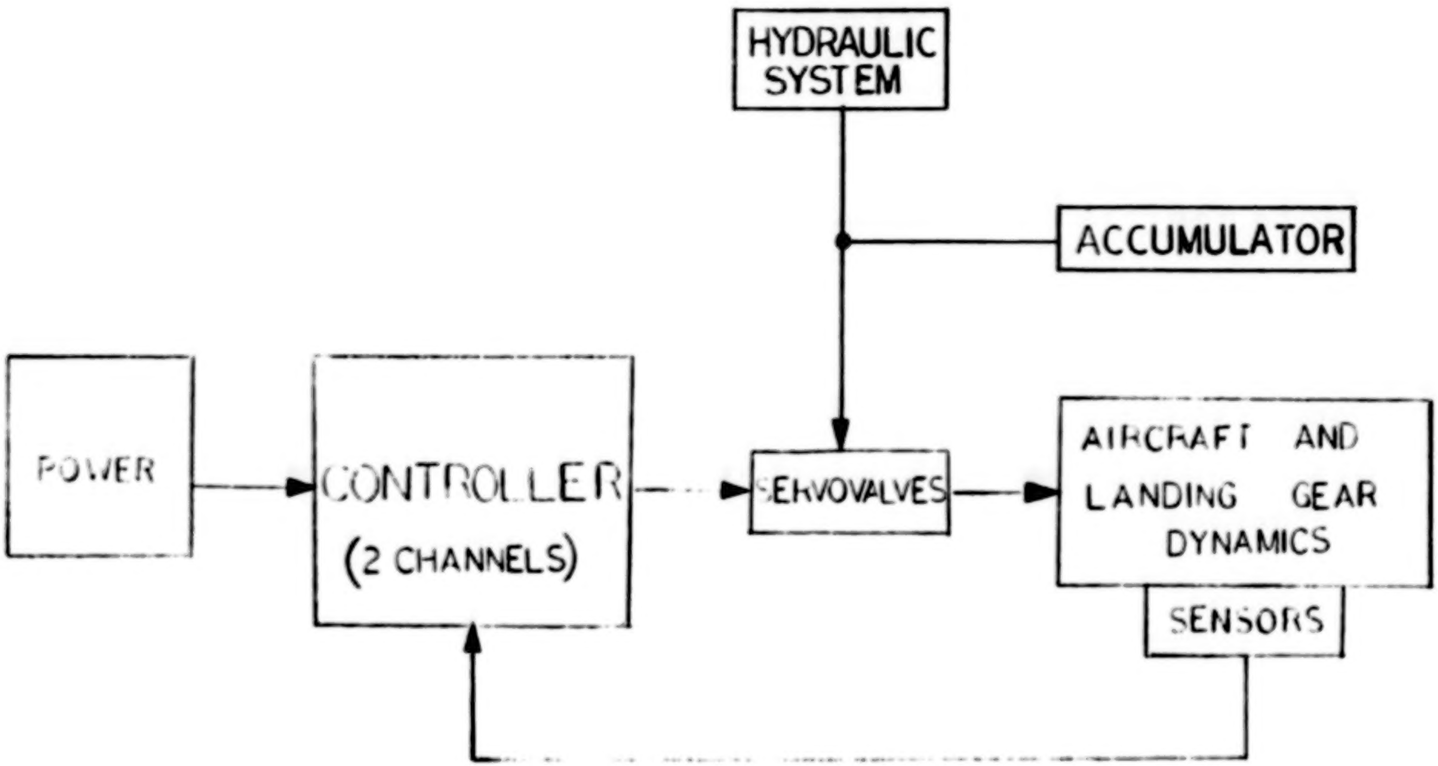


FIGURE B-1. ACTIVE CONTROL LANDING GEAR SYSTEM

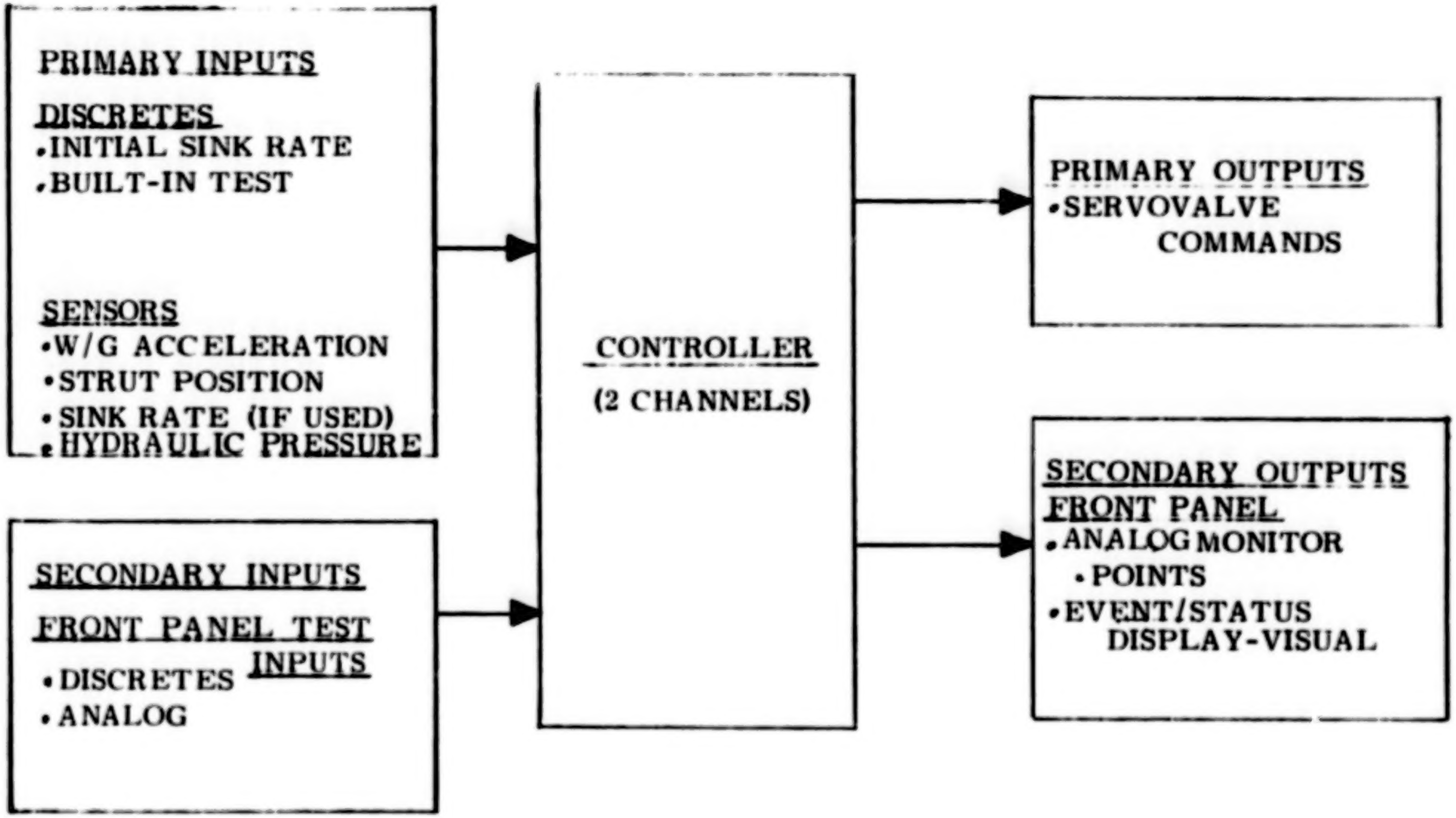
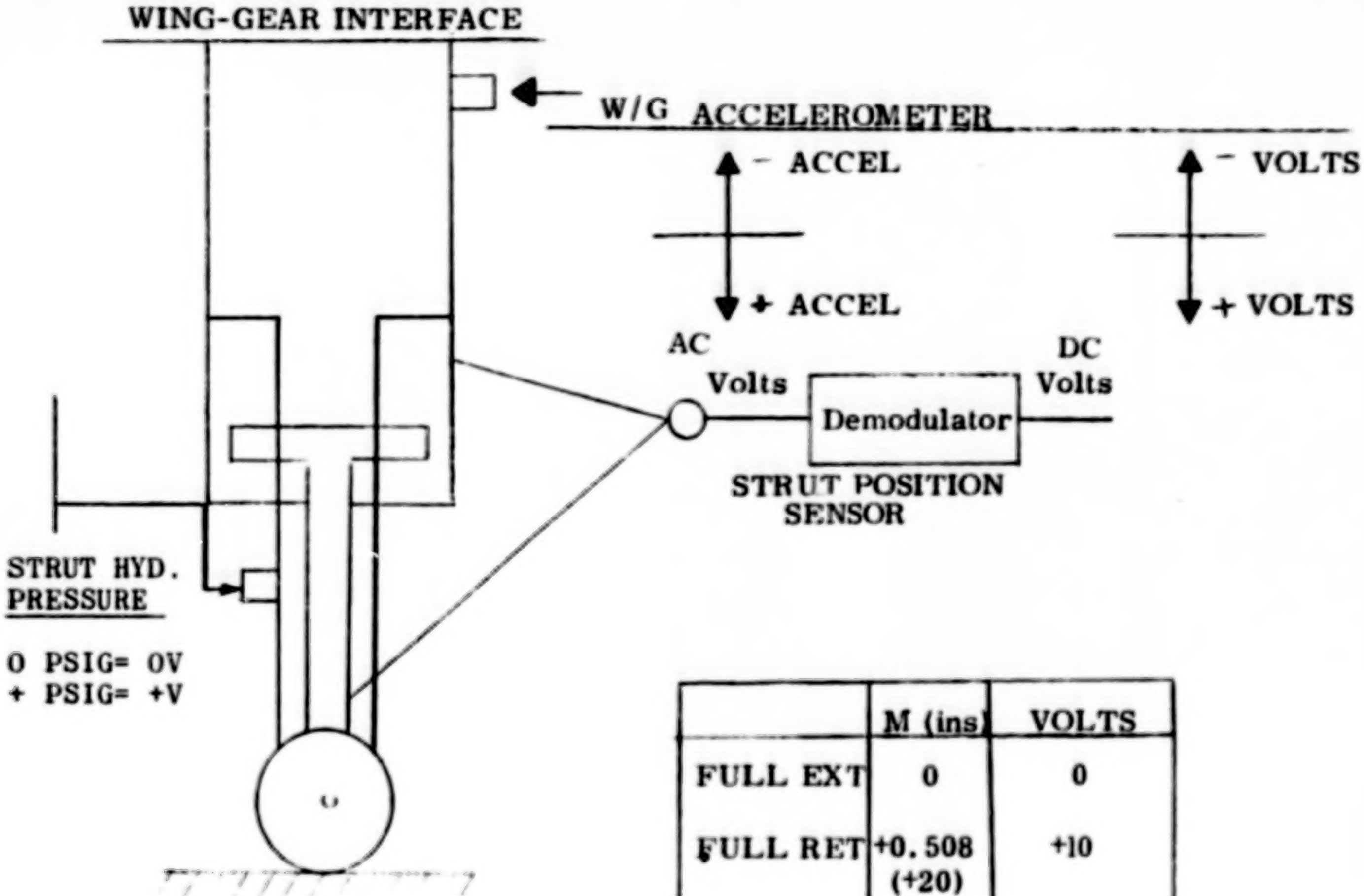


FIGURE B-2. INPUT/OUTPUT SIGNAL SCHEMATIC



	M (ins)	VOLTS
FULL EXT	0	0
FULL RET	+0.508 (+20)	+10

FIGURE B-3. SIGN CONVENTIONS AND TRANSDUCER POLARITIES

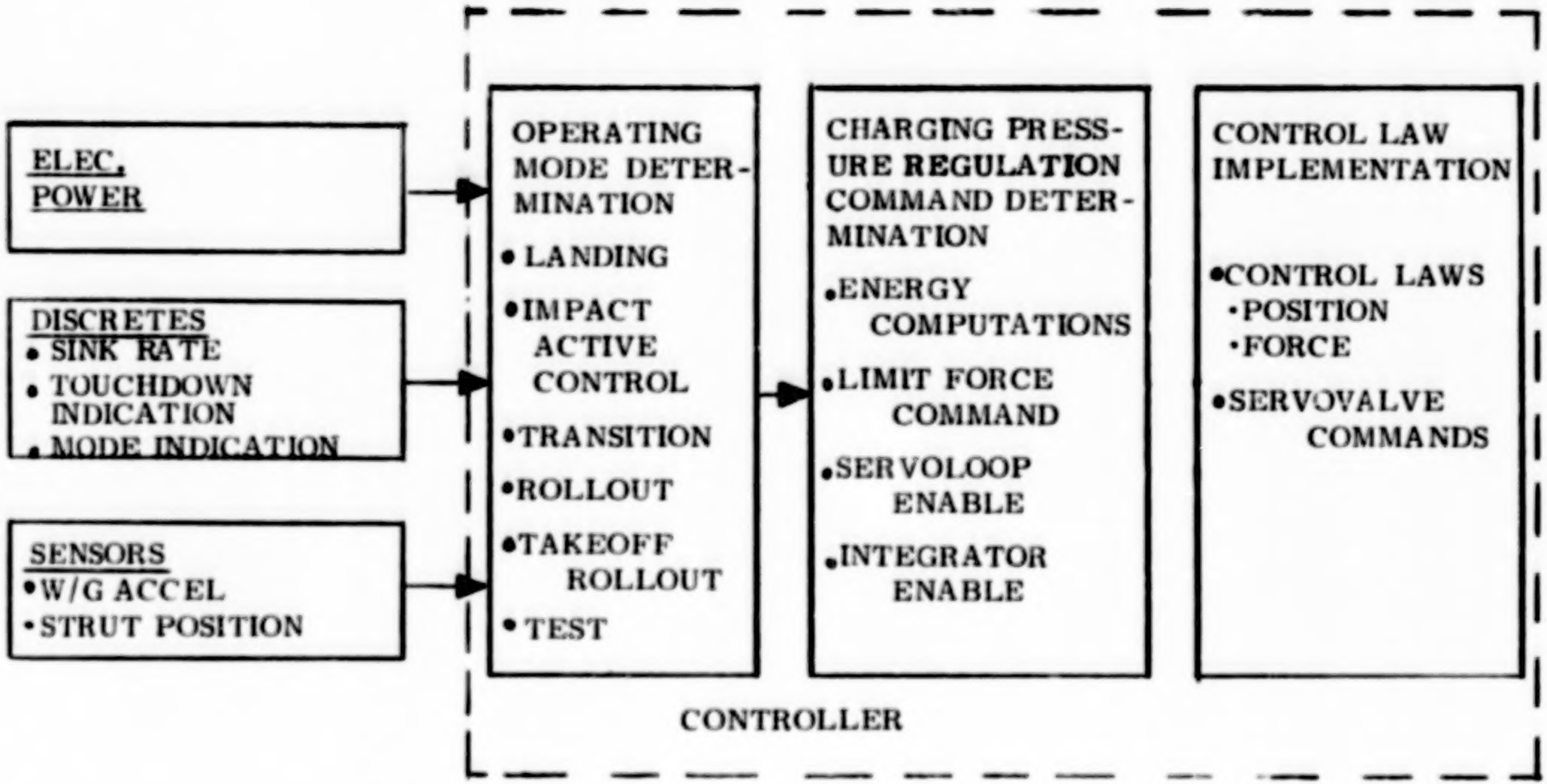


FIGURE B-4. BASIC FUNCTIONAL REQUIREMENTS

$$\text{Strut Work Potential} = \left(\frac{W}{g}\right)\left(g\ddot{X}_{wg}\right)\left(X_{SMAX} - X_S\right)$$

$$\text{Kinetic Energy} = \left(\frac{1}{2}\right)\left(\frac{W}{g}\right)\left(V_S - \int \ddot{X}_{WG}dt\right)^2$$

Active control shall be initiated when;

Strut Work Potential $\geq$ Kinetic Energy

Or, in equation form:

$$\boxed{\ddot{X}_{WG} \geq \frac{\left(\int \ddot{X}_{WG}dt + V_S\right)^2}{\left(2g\right)\left(X_{SMAX} - X_S\right)}}$$

Condition For Active Control Initiation

where,

$\ddot{X}_{WG}$	=	Wing-Gear Acceleration,	g's
$\int \ddot{X}_{WG}dt$	=	Integral of Wing-Gear Acceleration with respect to time,	m/sec (in/sec)
V_S	=	Initial Airplane Sink Rate,	m/sec (in/sec)
X_{MAX}	=	Maximum Strut Stroke,	m (in)
X_S	=	Strut Stroke,	m (in)
g	=	Gravitational Acceleration	= 9.804 m/sec^2 (386 in/sec^2)

FIGURE B-5

ENERGY RELATIONSHIPS

The wing-gear interface velocity at which transition occurs shall be computed as follows:

$$\boxed{V_T = \frac{F_{LI}^{\,2}}{2\,\frac{w}{g}\,R}}$$

Transition starts when V_T becomes equal to the wing-gear interface velocity (touchdown sink rate minus $\int \ddot{X}_{WG}\,dt$

where,

V_T	=	Transition Velocity,	m/sec (in/sec)
F_{LI}	=	Limit Force Command during impact	N (lb)
W	=	Airplane mass per main gear 1.388×10^4 Kg (30,600 lbm)	
R	=	Limit Force Transition Rate 4.448×10^5N (100,000 lb/sec as defined in Figure VII.	
g	=	Gravitational Acceleration 9.804 m/sec^2 (386 in/sec^2)	

FIGURE B-6

TRANSITION VELOCITY COMPUTATION

The limit force command from the beginning of the transition phase to the beginning of the rollout phase shall be computed as follows:

$$\boxed{F_{LT} = F_{LI} - RT}$$

IF $|F_{wg}| > F_{min}$ then $F_{LT} = F_D \text{ sign } F_{wg}$

IF $|F_{wg}| < F_D$ then $F_{LT} = 0$ and the force loop is open

where, F_{wg} = Wing-gear interface force

F_D = Preset limit force

F_{LT} = Limit Force Command During Transition, N (lb)

F_{LI} = Limit Force Command Prior to Transition N (lb)

R = Limit Force Transition Rate, 4.448×10^5 N/sec (100,000 lb/sec)

T = Time sec

FIGURE B-7

LIMIT FORCE COMMAND DURING TRANSITION PHASE

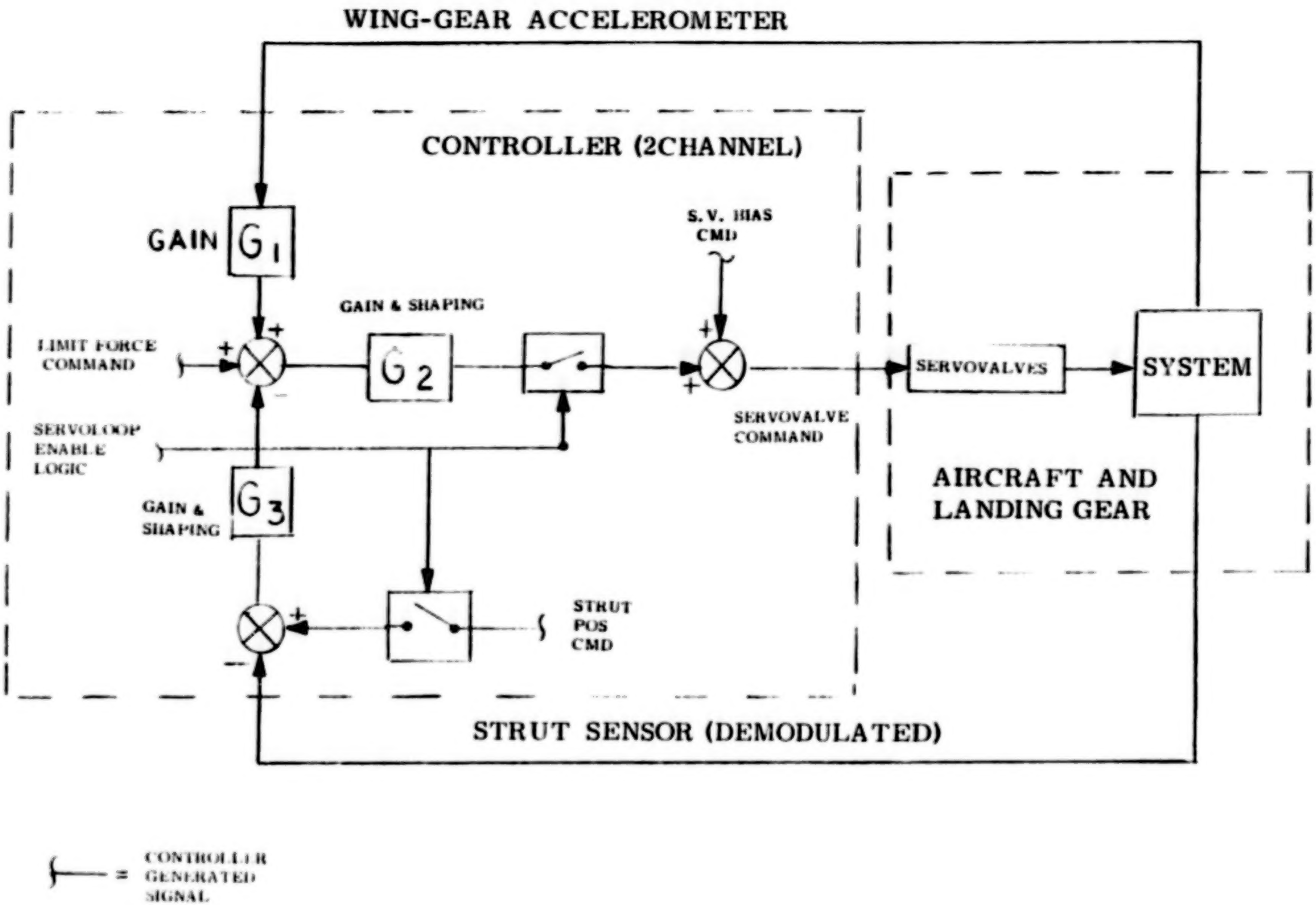


FIGURE B-8 CONTROL LAW FUNCTIONAL SCHEMATIC

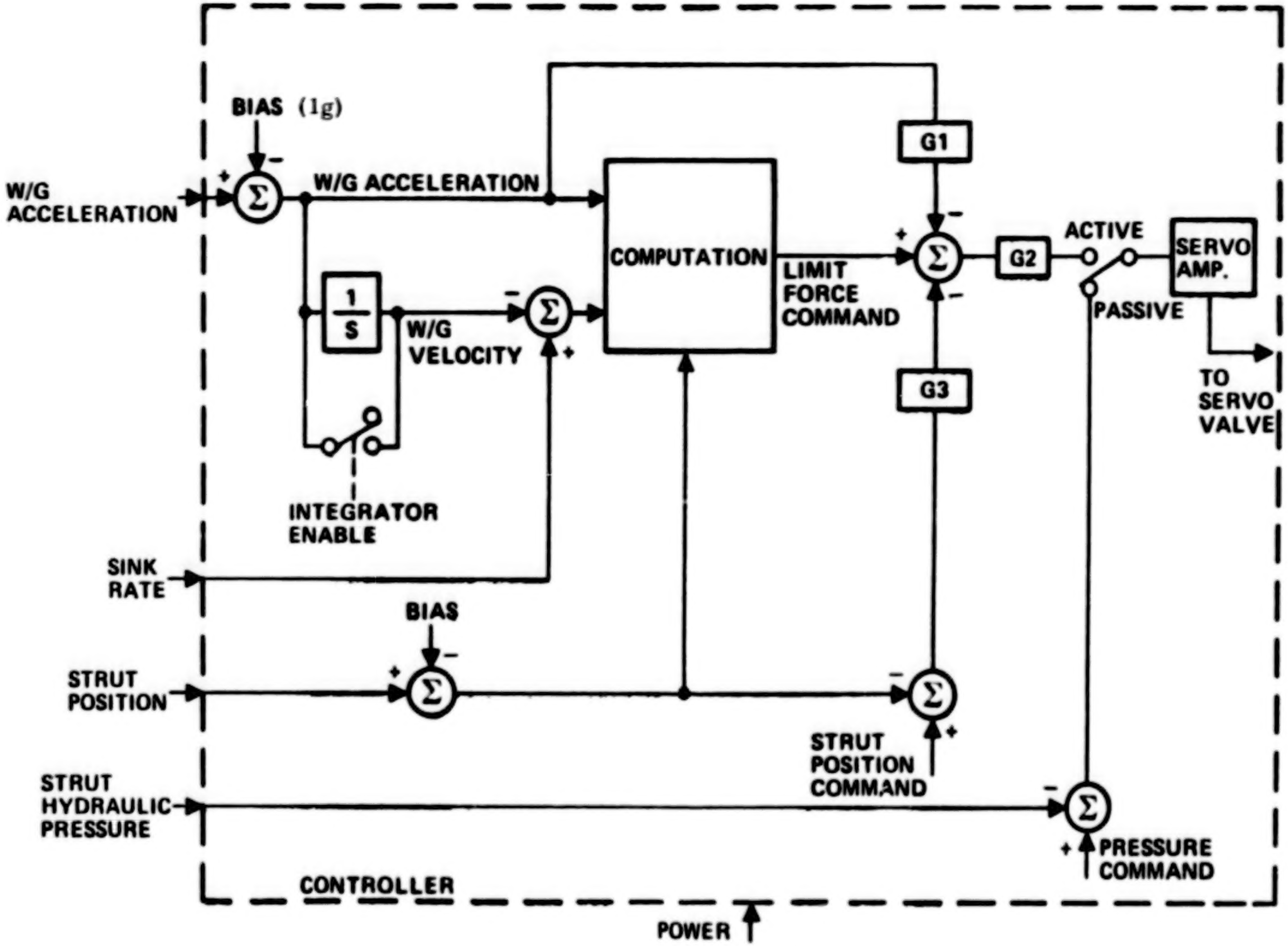
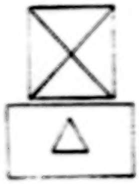
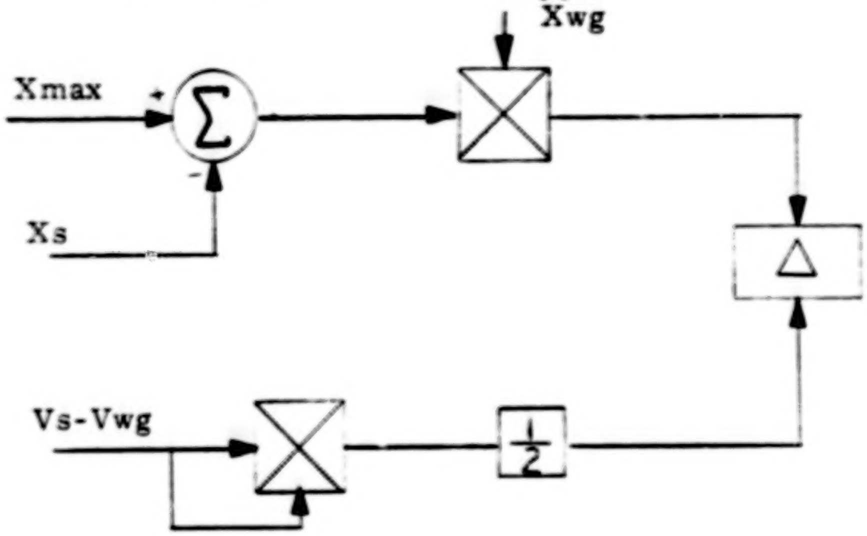


FIGURE B-9. CONTROLLER FUNCTIONAL SCHEMATIC

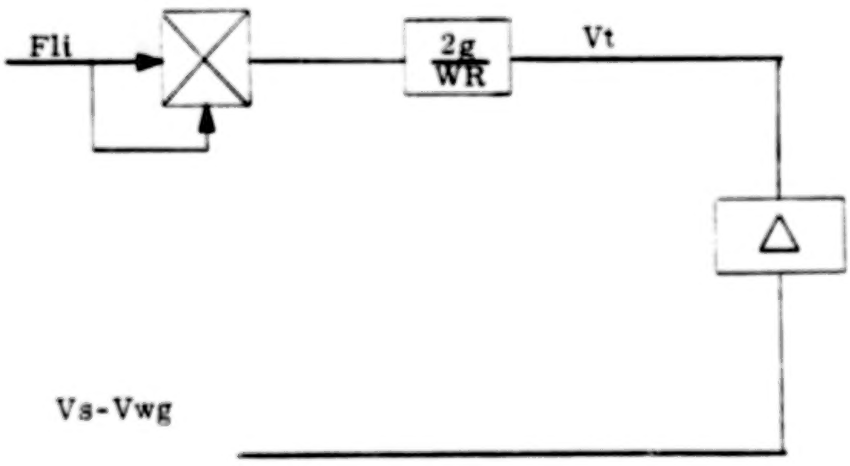


REPRESENT AN ANALOG MULTIPLIER

REPRESENTS AN ANALOG COMPARATOR



COMPARISON OF KINETIC ENERGY AND WORK POTENTIAL OF THE STRUT.



COMPARISON OF WING-GEAR VELOCITY AND TRANSITION VELOCITY

FIGURE B-10. COMPUTATIONS AND COMPARISONS

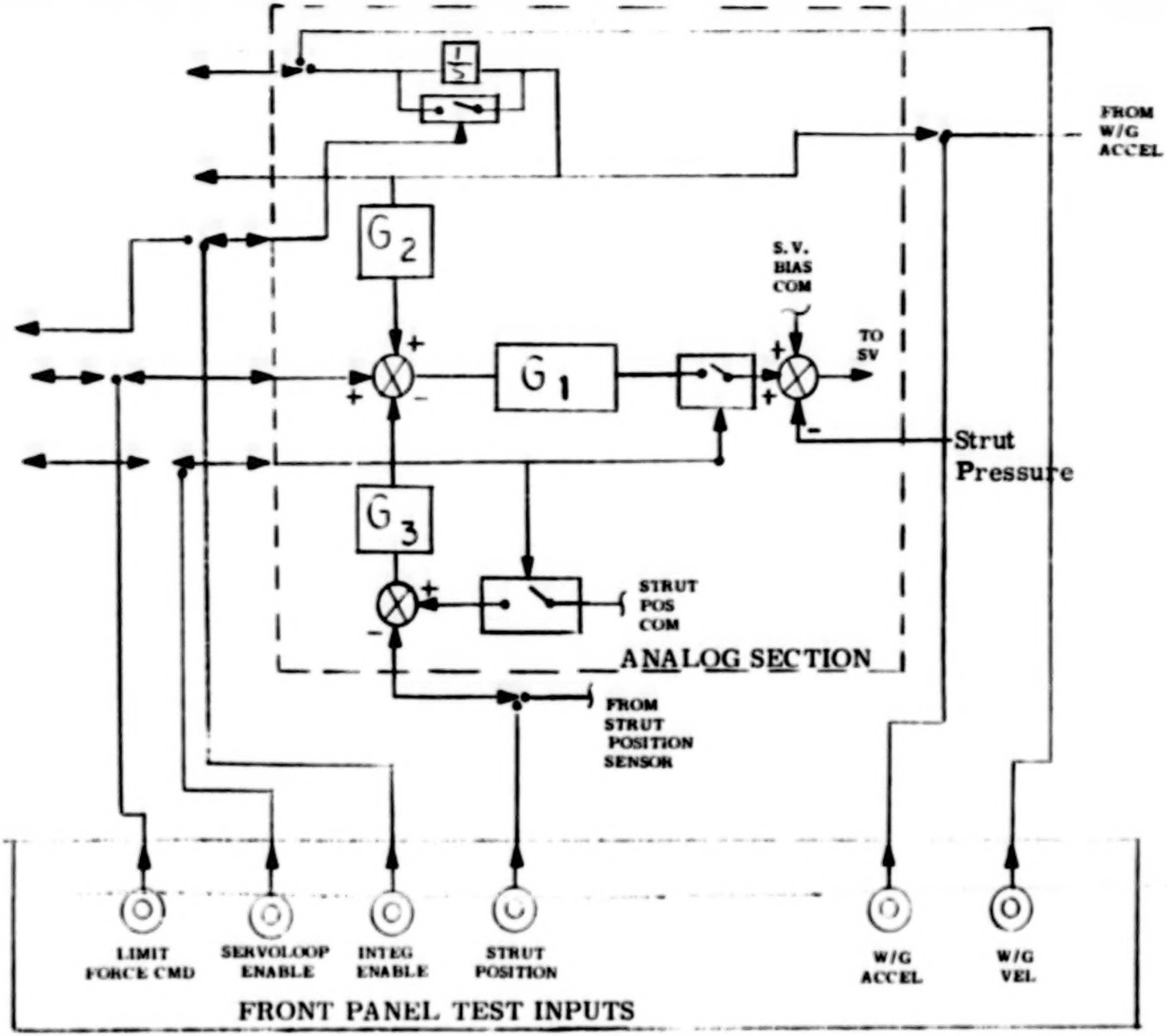


FIGURE B-11. FRONT PANEL INPUTS

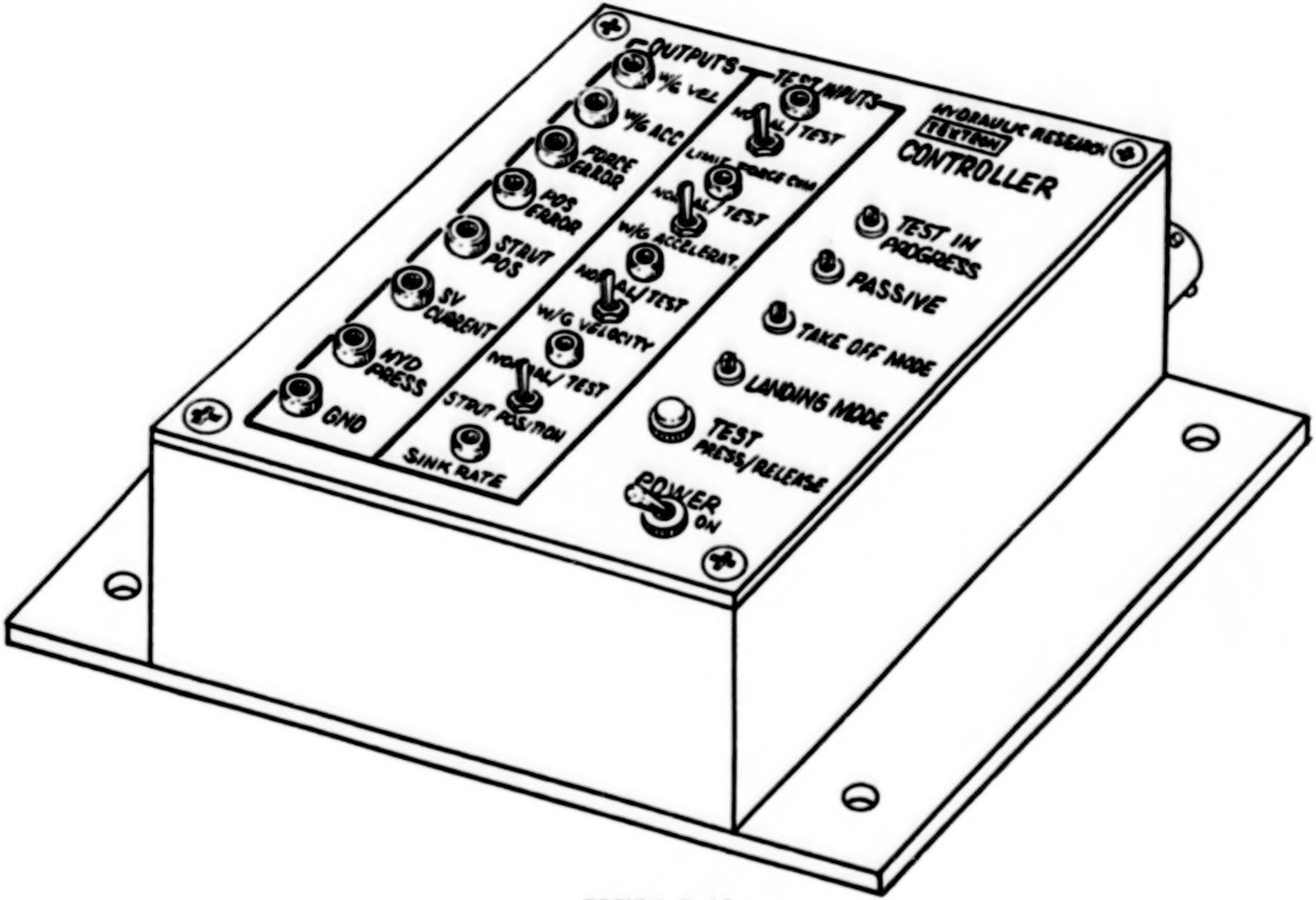


FIGURE B-12
CONTROLLER FRONT PANEL SKETCH

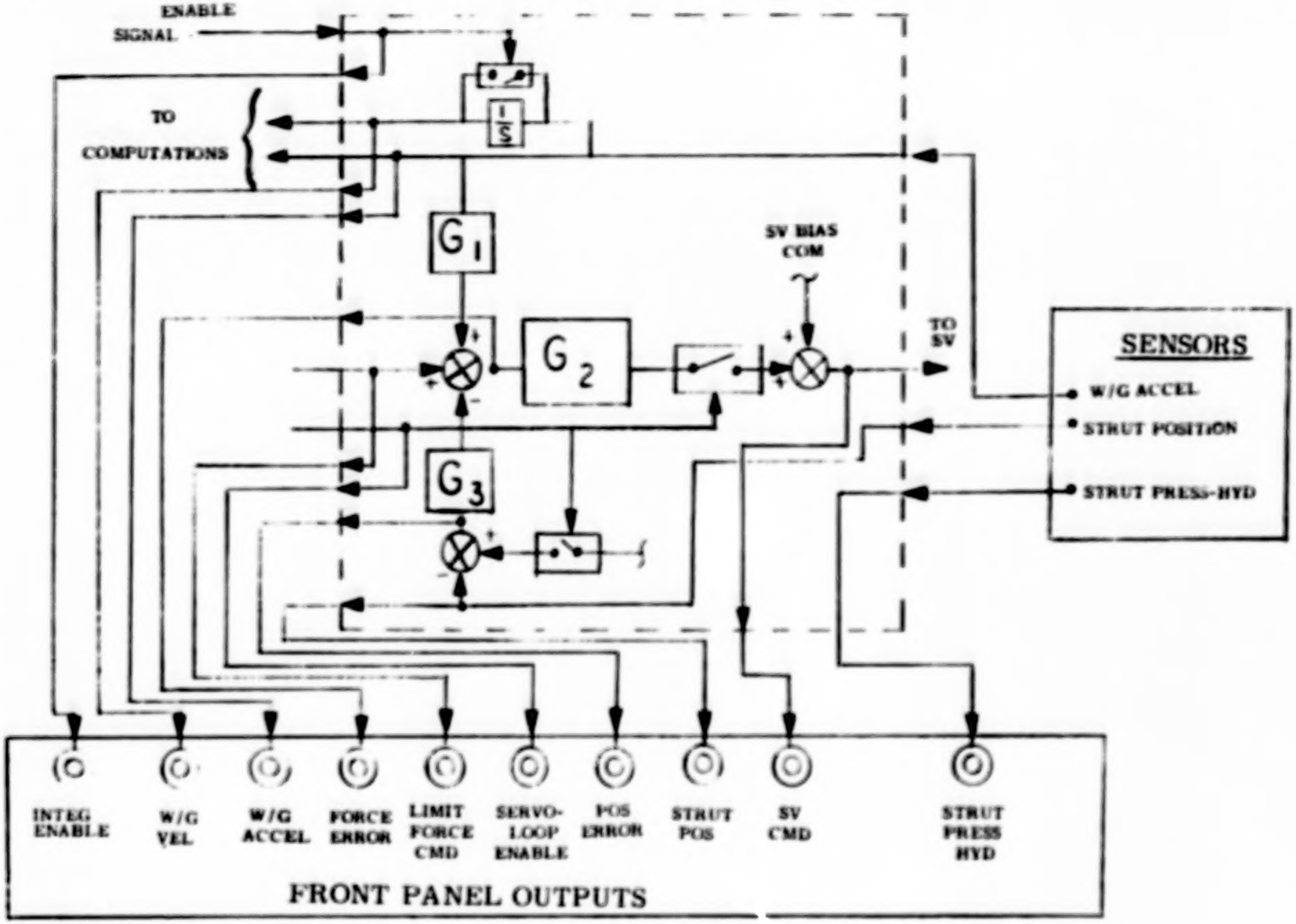


FIGURE B-13 FRONT PANEL OUTPUTS

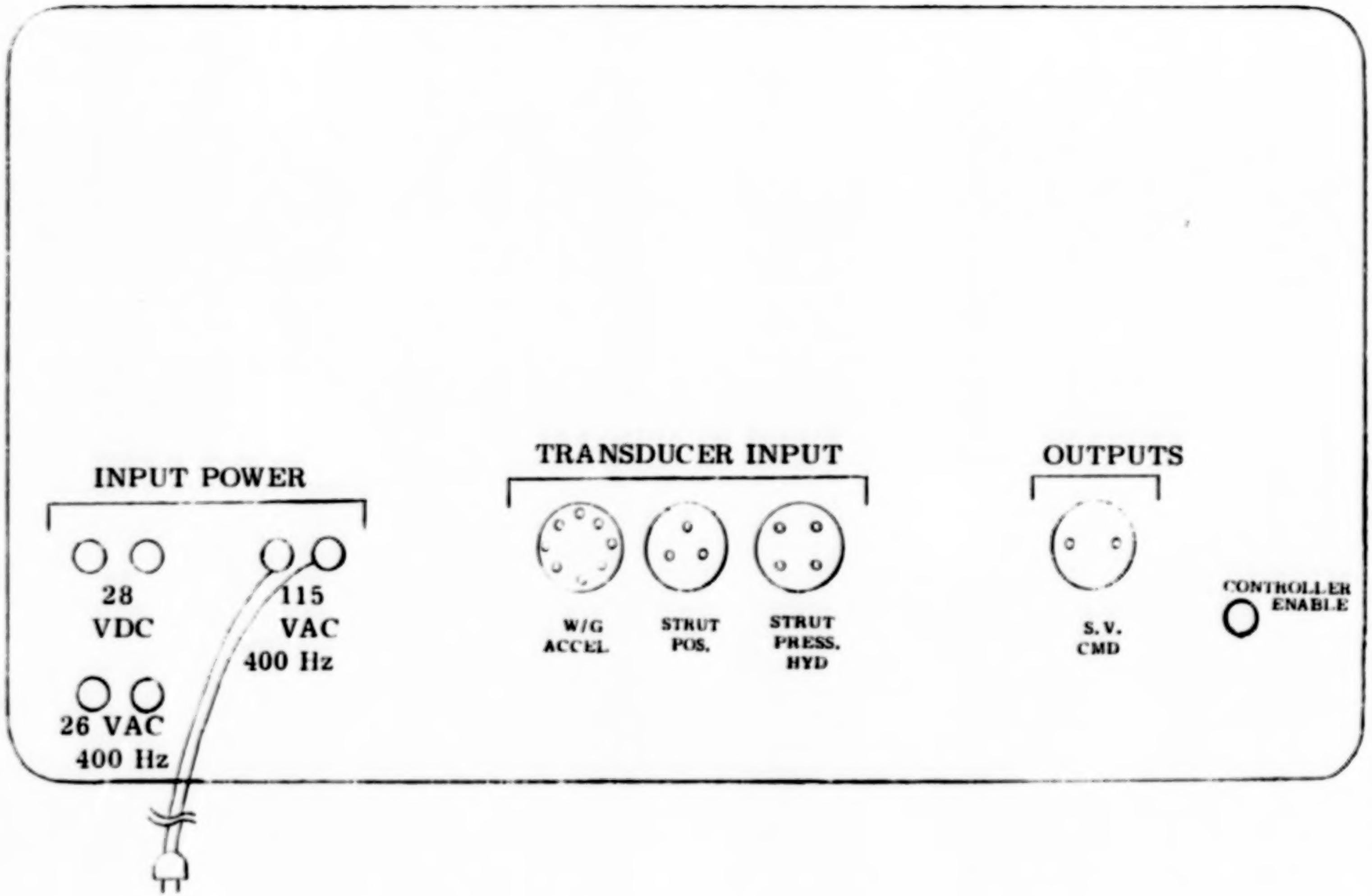


FIGURE B-14 . CONTROLLER REAR PANEL SKETCH

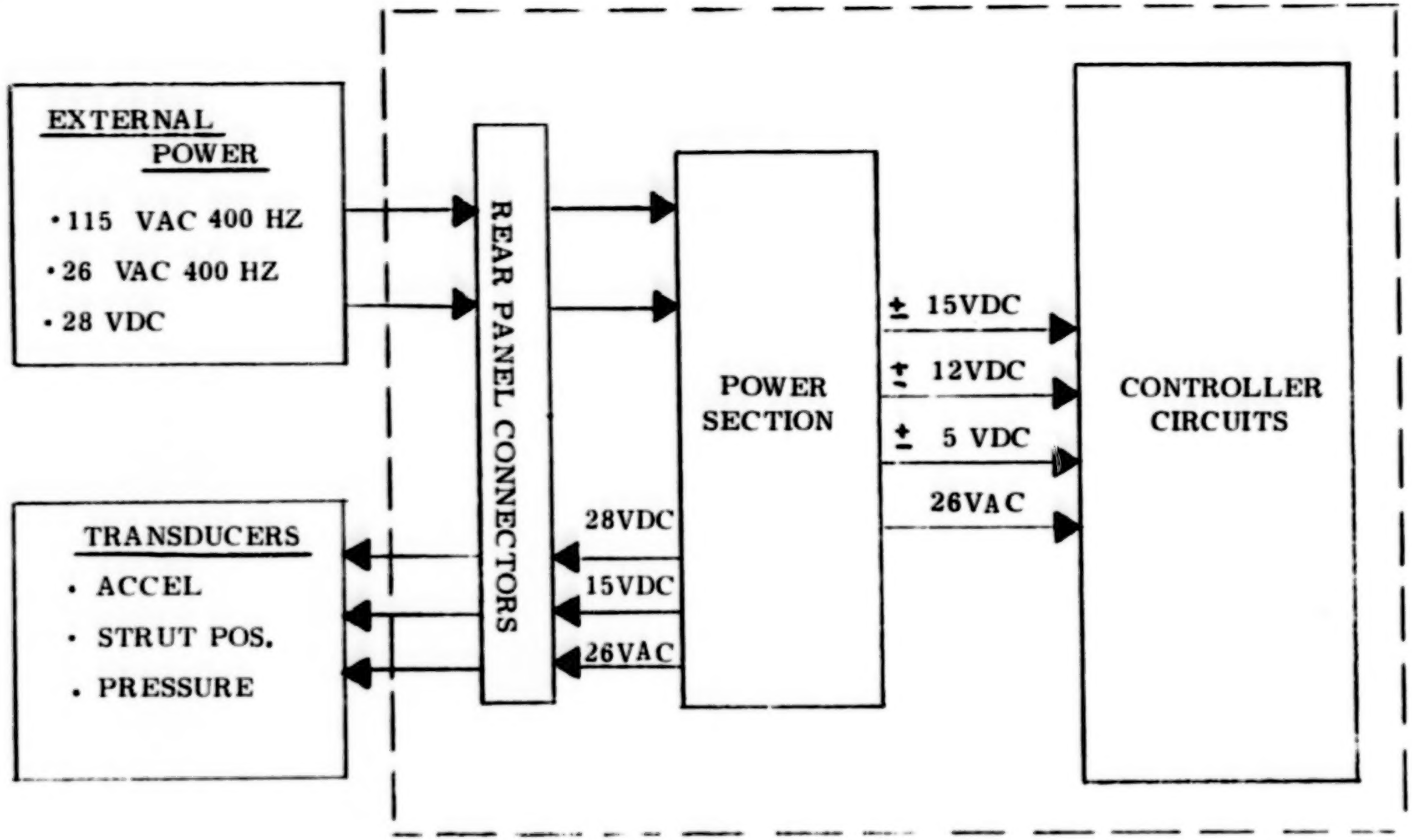


FIGURE B-15. POWER SECTION SCHEMATIC

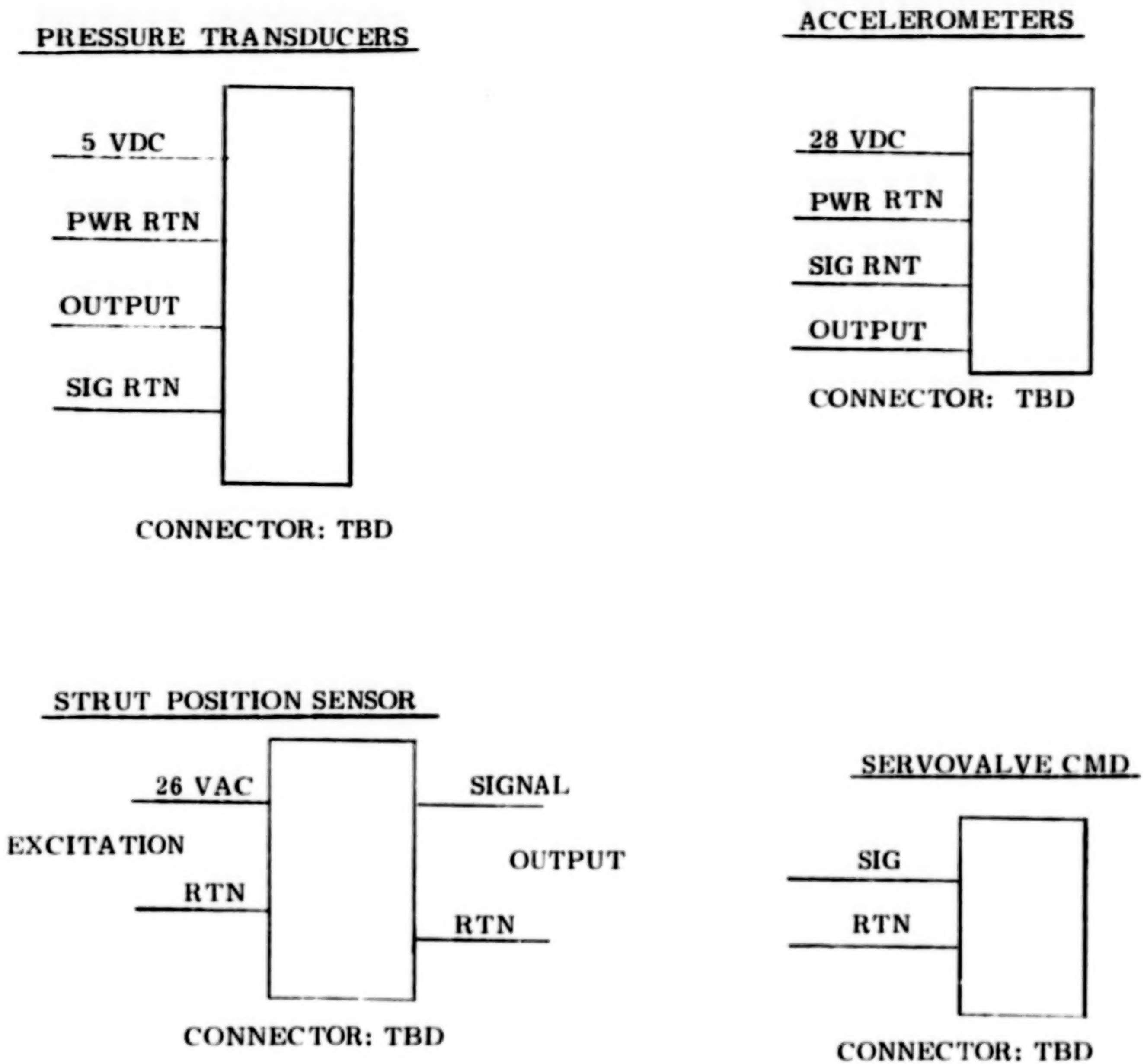


FIGURE B-16. EXTERNAL ELECTRICAL CONNECTORS

TABLE B-I

PRIMARY INPUT SIGNAL SPECIFICATIONS

PARAMETER	UNITS	TYPE	SOURCE	SIGNAL RANGE	POLARITY
Wing-Gear Acceleration	g's	Analog	Accelerometer	±4.12 g's	See Fig. 3.1-3
Strut Position	Meters (inches)	Analog	Synchro	0-0.508 m (0 to 20 in.)	See Fig. 3.1-3
Initial Sink Rate	Meters/sec (inches/sec)	Analog	Front Panel Control or Sink rate sensor	0-2.54 m/s (0 to 100 in/sec)	--
Strut Pressure-Hydraulic	Volts	Analog	Pressure Transducer	0-1.728x10^4 KPa (0-2500 psi)	0 PSI= 0 Volts + P produces +V
Touchdown indication	volts	Logic	Wheel Generator	0-2400 RPM	Rotation = + volts
Takeoff or Land	volts	Logic	Aircraft scissors switch	0 or 15 VDC	15 VDC = Weight on gear.

TABLE B-II

SECONDARY INPUT SPECIFICATIONS

PARAMETER	UNITS	TYPE	SOURCE	SIGNAL RANGE	POLARITY	SCALE FACTOR
Limit Force Command	N (lbs)	Analog	Front Panel Jack	8.846×10^{5} N (200,000 lbs)	+ N = - Accel.	1.102×10^{-5} V/N (4.902 x 10 -5 V/lb)
Wing-Gear Acceleration	g's	Analog	"	± 5 g	See Fig. 3.3	2 MV/g @ 5 vdc excitation.
Wing-Gear Velocity	m/sec (in/sec)	Analog	"	0-2.54 m/sec (0 to 100 in/sec	See Fig. 3.3	3.937 v/m/sec (0.1 Volts/in/sec)
Strut Position	meters (inches)	Analog	"	0-.508 m (0 to 20 in)	See Fig. 3.3	19.68 v/m (0.5 volts/inch)
Servoloop Enable	Volts	Logic Level	"	(*)	--	--
Integrator Enable	Volts	Logic Level	"	(*)	--	--

* Logic 1= 0 ± 0.5V
Logic 0= +2.4 to +5V

TABLE B-III

SECONDARY OUTPUT SPECIFICATIONS

PARAMETER	UNITS	TYPE	FRONT PANEL SOURCE		SIGNAL RANGE	SCALE FACTOR
			Jack	Visual Display (LAMPS)		
Servovalve Command	ma	Analog	X		± 10 V	176 ma/(V Force Error)
Wing-Gear Acceleration	g's	Analog	X		± 10 g	1.8 V/g
Strut Position		Analog	X		0 to .508 m (0 to 20 in)	9.843 v/m (0.25 V/in)
Strut Position Error		Analog	X		0 to .508 m (0 to 20 in)	(9.843 v/m) 0.25 V/in
Strut Pressure-Hydraulic	KPa (psi)	Analog	X		$0-1.72\times10^{4}$ KPa (0 to 2500 psi)	0.00232 V/KPa (0.016 mv/psig)
Force Error	N (lbs)	Analog	X		8.896×10^{5} N (200,000 lb)	1.102×10^{-5} V/N (4.902×10^{-5} V/lb)
Limit Force Command	N (lbs)	Analog	X		8.896×10^{5} N (200,000 lb)	1.102×10^{-5} V/N (4.902×10^{-5} V/lb)
Wing-Gear Velocity	m/sec (in/sec)	Analog	X		0-2.54 m/sec (0 to 100 in/sec)	3.937 v/m/sec (0.1 V/in/sec)
Servoloop Enable	--	Logic Level	X		--	--
Integrator Enable	--	Logic Level	X		--	--
Takeoff Mode	--	Visual		X	--	--
Landing Mode		Visual		X	--	--

TABLE B-IV

CONTROL LAW TRANSFER FUNCTIONS

SYMBOL REF. FIGURE C-8	TRANSFER FUNCTION	PARAMETER VALUES
G_1	K_{WG}	K_{WG} = 1.0 v/v
G_2	$\dfrac{(S^2+2\zeta_2 W_1 S+W_1{}^2)(T_1S+1)(T_3S+1)K_A}{(S^2+2\zeta_1 W_1S+W_1{}^2)(T_2S+1)(T_4S+1)}$	T_1 = 0.0281 sec T_2 = 0.0141 sec T_3 = 0.001 sec T_4 = 0.0001 sec W_1 = 251.2 rad/sec ζ_2 = 0.1 ζ_1 = 5.1 KA = 176 ma/v nominal (variable from 50% to 200% of nominal)
G_3	$\dfrac{K_F}{T_FS + 1}$	K_F = 0.00098 V/V T_F = 0.1 sec S = Laplace Operator -sec^{-1}

XIII. REFERENCES

1. Ross, Irving; and Edson, Ralph: An Electronic Control for an Electrohydraulic Active Control Aircraft Landing Gear. NASA Contractor Report 3113, 1979.

1. Report No. NASA CR-3298	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Flightworthy Active Control Landing Gear System for a Supersonic Aircraft		5. Report Date June 1980
		6. Performing Organization Code
7. Author(s) Irving Ross		8. Performing Organization Report No.
9. Performing Organization Name and Address Hydraulic Research Textron Valencia, California 91355		10. Work Unit No.
		11. Contract or Grant No. NAS1-15455
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Contractor Report
		14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitor: John R. McGehee
Final Report

16. Abstract

Hydraulic Research, under NASA Contract NAS1-15455, designed a flightworthy active control landing gear system for a supersonic aircraft, the purpose of which is to minimize aircraft loads during takeoff, impact, rollout and taxi . The design consists of hydromechanical modifications to the existing gear and the development of a fail-safe electronic controller. Analytical results indicate that for an aircraft sink rate of 0.914 m/sec (3 ft./sec.) the system achieves a peak load reduction of 36% during landing impact.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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